QUALITY TIME: TEMPORAL CONSTRAINTS TO CONTINUAL PROCESS DEVELOPMENT IN THE AIR FORCE

BY

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APPROVAL

The undersigned certify that this thesis meets master's-level standards of research, argumentation, and expression.

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ABSTRACT

This work implements a deductive system-dynamics methodology to analyze the application of quality management policies to an Air Force system. The work provides an alternate explanation to the existing body of literature on the failure of Total Quality Management (TQM) and Quality Air Force (QAF) programs. The modeling and simulation in this work indicated that the time between activities and the repeatability of activities heavily impact their probability of success. Quality programs are one side of a two-sided equation; they increase the efficiency of a system thus reducing rework and waste. Simultaneously, forces of entropy or chaos continually degrade the efficiency of that same system. The strength and speed with which quality management programs can increase efficiency are directly dependent upon three time constants: the time required for a person to gain competency with a task, the time required for a unit to generate new ideas, and the time required for new ideas to be implemented and evaluated. The work argues that the length of these three time periods is a necessary, but not sufficient, condition to successfully implement quality programs. The longer these periods, the more prone to failure quality programs become.

As these three time constants get longer, the strength of quality programs against entropy decreases, and the more difficult the implementation of quality programs becomes. At some point, time constants become so long that it is impossible obtain quality from process; quality must be obtained through testing and correction of deficiencies. This work also indicates that there may be systemic issues associated with capturing experience inside Air Force units. This work assists commanders in determining if the time constants of their units are amenable to quality programs. It should also assist in their ability either to advocate for adoption of TQM, request additional resources for implementation, or push back with a time-based argument that TQM is incorrect for their unit and mission.

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Chapter 1

Introduction

In 1988, the United States Department of Defense (DoD) enacted the Total Quality Management (TQM) Master Plan as the "strategy for continuously improving performance at every level and in all areas of responsibility."[1] TQM exists as a comprehensive management philosophy seeking to increase efficiency by reducing re-work through an iterative process focused on quality. A successful implementation theoretically grants one of two things: increased productivity given the same resources or equal capacity with decreased resources. This is achieved through iterative reduction in errors, at every level of management over several years, resulting in less waste and thus higher performance.

The history of process improvement dates back to the 1920s, when statistical tools were first introduced as a process for measurement and quality control in manufacturing. Assisted by the vast amount of experience with manufacturing and production from WWII, an explosion of management techniques occurred in the 1950s. Among its grandfathers TQM counts the great minds of Deming, Juran and Feigenbaum. With the initial goal of increasing profitability by reducing waste and rework, the tools, techniques and methods of the era were implemented. Over time, successes and failures with various aspects of quality management gave birth to theory. With increased computational power, the ability to store and track metrics enabled TQM to become a comprehensive management philosophy beyond process improvement techniques.

In 1978, Air Force General Bill Creech implemented his own flavor of TQM onto Tactical Air Command (TAC). With respect to operational flying, General Creech's implementation was successful. The Air Force,

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[1] Corporate Author: DoD, "DoD Total Quality Management Master Plan," August 1988, 1.

following the DoD mandate in 1988, implemented TQM service-wide with the goal of reducing the cost of defense, combating erosion in the industrial base and making the Air Force more competitive.[2] The Air Force believed that quality could be achieved in one of two ways: either quality is baked into the process or quality must be obtained through testing and correction of deficiencies. Furthermore, the Air Force concluded that if quality is baked in it comes “for free” but if quality must be inspected or tested in it comes at a cost.

As a manager or a leader, it is nearly impossible to argue against the core quality management claim that “Quality can be put into every management activity.”[3] However, while such a concept sounds irrefutable, if one asks “can the same implementation place quality into every management activity,” the answer might be no. In the face of increasing complexity, specialization, not standardization, is usually the recommended policy. The Air Force believed that Total Quality Management (TQM) through its tailorability would be up to the challenge. However, history has borne out that TQM failed to “catch” and the results initially envisioned across the Air Force were not delivered. Still, TQM elements have lived on in in the Air Force lexicon as AFSO21, Airmen Powered by Innovation, ISO 9000 series guidance and education of process control tools such as Six Sigma or green/black belt training.

In both the civilian and military sector, the failure of TQM is usually attributed to implementation, not theory.[4,5] After three decades of tinkering, TQM styles of management no longer receive heavy support from AF leadership. Nevertheless, AF leadership continues to push

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[2] Corporate Author: USAF Systems Command, “Making Total Quality Managment Happen,” June 1989, 4.
[3] Bill Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You* (New York: Truman Talley Books/Plume, 1994), 1.
[4] Robert Craig, “Quality in the Operational Air Force: A Case of Misplaced Emphasis” (Air War College, 1994), 23.
[5] Mark Brown, Darcy Hitchcock, and Marsha Willar, *Why TQM Fails and What to Do about It.* (New York: IRWIN Professional Publishing, 1994), 1.

quality process-control elements, and these necessarily come with an overhead burden. It is unclear if these activities will ever become value-added processes or will remain a net drain on productivity in the Air Force. This thesis examines if the theory of TQM is fundamentally misaligned with some or all structural elements of the Air Force mission; specifically, if context can make implementation of quality programs time-prohibitive in some units. If no evidence of systemic misalignment between the Air Force mission and the theory of TQM can be found, then the work will support the assertion that failures of TQM in the Air Force were failures of implementation or execution. If fundamental misalignment is found, then the existing implementation of process-control tools at all levels of the Air Force (AFSO21, etc.) must be re-evaluated. Depending on the results, a targeted message of how leadership should continue supporting quality efforts will be crafted.

In Chapter 2, the theory of TQM is explained at a structural level. A literature review is performed to examine existing theory and practice for the success and failure of TQM in the private sector. Special note is given to the structure and mechanisms leading to process improvement. In addition, this review examines historical Air Force plans for TQM implementation. To assist in this effort, the conclusions of several case studies, during and post-TQM implementation in various units, are included. The Literature Review finds many explanations of why quality programs might fail in Air Force units. In addition, the cyclical nature of quality programs operates under the assumption of learning curve theory. It is assumed that processes to be iterated upon are both repeatable and performed in short interval. Finally, a method for inquiry into complex social, technical and managerial systems, known as Systems Dynamics (SD), is presented.

Based on evidence gathered, Chapter 3 presents a structural analysis of TQM, with its principles cast in the language of Air Force operations. Often single elements such as “maintenance culture” are given as reasons for why a policy succeeds in one organization or fails in another. While it is true that culture may play a role in success, single-variable reasons are insufficient as they do not speak to the scope of the system and a change upon that system. Chapter 3 defines the scope of TQM, setting the endogenous and exogenous variables for an organization which manages a process. The normal mode of operation for this closed system would be the historical *business-as-usual*. It is argued that as TQM theoretically applies to any level of management which owns a process, it is valid to abstract all levels of management into a single, abstract system-process model. TQM then becomes a policy which can be applied to the abstract system model. The implementation of TQM as a policy onto a system should produce changes to the operation of the system, however, the direction and magnitude of the changes are not obvious and often can counter intuition. Based on the literature review, Chapter 3 breaks the concept of a system into five fundamental "building blocks" labeled as "Molecules of Structure." Chapter 3 simulates these molecules of structure to validate that the model can abstract the theory of TQM into a simulation.

As TQM is a policy that operates iteratively over a long timeline, Chapter 4 implements the structural elements of Chapter 3 in a complete System Dynamics (SD) model and simulates it for several years. This model possesses similarities to and draws upon the work of Dr. Brad Morrison from 2008 through 2011. His work serves as a path to examine the impact of policy on a pipeline-system. In this thesis an SD lens is leveraged to view the Air Force implementation of the TQM policy.[6] Morrison's work encapsulates the core concepts of TQM theory examining learning curves, experience, efficiency with process, and

[6] Brad Morrison, "Process Improvement Dynamics Under Constrained Resources: Managing the Work Harder versus Work Smarter Balance" (MIT, 2011), http://people.brandeis.edu/~bmorriso/documents/BalancingHrdrSmrtr2011.pdf.

resource constraints. As Morrison's work contains the same structural elements as the theory of TQM, and represents work-improvement policy applied to a management system, it is valid to use this to view the impact of implementation of TQM on an Air Force system. This model grants a unique ability to link soft systems, such as experience, with more concrete structures such as efficiency, production rate, and resources required in a process. This enables investigation of basic assumptions about implementing TQM in Air Force systems.

Chapter 5 concludes the work, discusses findings, and makes observations about the interplay between time and process improvement. The work concludes that three external time constants play a large systemic role in determining if a TQM-style policy can succeed in a given unit.[7] The impact of short or long process-cycle times and the rate of entropy or change in the system can heavily contribute to the success of quality programs in a given unit. The work offers an alternate explanation to existing reasons why TQM failed and quality programs continue to fail in much of the Air Force. It concludes that if the time-cycles required for learning are too long, or positive aspects of quality programs too easily decay, then the theoretical underpinnings of quality management cannot be applied to that Air Force function.

[7] The term constant typically refers to static or unchanging variables. Within system dynamics three primary structures exist: stocks, flows, and variables. The term constant is used to refer to variables that cannot change within a simulation. The three time constants are referred to as constants within this work as they do not change during simulation. In chapter four the time constants are varied to illustrate the impact of their change on system behavior. Even though the constants are changed they are still considered constants, not variables, as they do not change during simulation runtime.

Chapter 2

Literature Review

There is something alluring about the statement "You can add quality to any management process."[1] On face value one cannot argue against such a statement; any manager innately knows they could always have "done better" on previous projects. A potential problem with such thinking is that a one-size-fits-all solution, or a tailorable process, will be able to add quality to every management process. Moreover, there is also an issue of falsifiability when combined with the reasoning that the process did not fail, the implementation did.[2] Thus, the process or technique is infallible, but the people who implemented it made the mistake. Case studies, based on their unit of analysis, will always be able to find fault with the implementation of any policy on a system. However, case studies typically lack the ability to make systemic claims as they lack the extensibility or external validity to other organizations and context. To make a systemic argument either for or against such a philosophy, a concrete example or set of examples will have difficulty moving beyond a specific context unless a large sample size is available. In examining TQM-style management in the Air Force, many case studies are available but aggregate enterprise level data does not exist.[3] To frame research, four broad categories of writing are included in this literature review:

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[1] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 1.

[2] Thomas Kuhn, *The Structure of Scientific Revolutions*, 3rd ed. (Chicago, IL: University of Chicago Press, 1996). Karl Popper's contribution to philosophy was his realization that many theories stuck around because they were simply unfalsifiable. Effectively there was no data that could ever exist which would prove the theory wrong. This statement is somewhat unfalsifiable since human activities are never perfect, there will always be a human mistake which can be pointed to as the cause of failure. Thus, the process improvement, (based on the Theory of TQM, can always be defended as the human will always make at least one mistake.

[3] The irony of this should not be missed; metrics are the lifeblood of TQM and the enterprise did not track this data.

1. Civilian industry literature on implementation and theory of TQM.
2. Air Force authors on the theory of TQM and the Air Force
3. Air Force case studies on attempted implementations of TQM
4. System Dynamics as a methodology for deductive investigation of cyclical processes

This literature review gathers information and techniques to enable a systemic analysis on the theory of TQM in the Air Force. Implementing such an approach enables understanding of the extensibility of TQM and assists in scoping the applicability of TQM. This literature review is neither comprehensive nor is it a manual for implementing TQM. The goal is to provide sufficient evidence to understand the underlying premises of TQM such that a theoretical model can be constructed and simulated based on broad objectives.

TQM Authors—A Brief Synopsis of Quality Management Evolution

Frederick Taylor is considered the father of "scientific management" as the first known author to implement statistical methods in production. His book *Shop Management* laid the ground work for measuring effective metrics and how their documentation could assist in improving factory processes.[4] The core component Taylor's work was the idea of tracking outputs, finding patterns, and then using that data to improve process in the next generation. Nearly 100 years later, proponents of TQM nearly universally recommend using the latest technology to record and process statistics and track metrics. Credit is given to Joseph Juran in his famous quality-control handbook for first defining quality when he asked the question "what cost would disappear if all defects disappeared?" His answer was that quality was the cost of

[4] Taylor Frederick, *Shop Management* (New York, NY: Harper & Brothers, 1919).

defects in the manufacturing process.[5] He reasoned that a perfect implementation with 100 percent efficiency was one with no defects. The difference between perfection and the current defect rate (known as the yield in manufacturing) was the cost borne by the organization through less than perfect quality. An anecdote of this style of thinking is seen in present-day manufacturing. When trying to understand why space launch was so expensive, the founder of SpaceX, Elon Musk, reasoned that the cheapest way to manufacture anything was to gather the needed raw materials and wave a "magic wand" to turn them into a launch vehicle. The difference between the cost of the raw materials and the rocket was reasoned to be the cost of production. Thus, the cost of quality would be considered the component of production cost required beyond a perfectly efficient assembly.

First outlined in his book *Out of the Crisis*, Deming constructed fourteen management principles for quality in management. These principles range from the pragmatic to the managerial to the strategic:

1. Create constancy of purpose for improvement of product and service
2. Adopt the new philosophy
3. Cease dependence on mass inspection
4. End the practice of awarding business on price tag alone
5. Improve constantly and forever the system of production and service
6. Institute training
7. Drive out fear
8. Institute leadership

[5] Joseph Juran, *Juran's Quality Handbook*, 4th Edition (United States of America: The McGraw-Hill Companies, 1951), 2.5, 3.4.

9. Break down barriers between staff areas

10. Eliminate slogans, exhortations, and targets

11. Eliminate numerical quotas

12. Remove barriers to pride of workmanship

13. Institute a vigorous program of education and retraining

14. Take action to accomplish the transformation[6]

Deming's genius was several-fold. First, he realized that the individual was more than his/her labor. Individuals were not only the mechanism of labor, the individual was the mechanism for improving their own output. Second, he realized that culture was a driving force inside an organization. If a job was more than just a pay check to a person and they took pride in their work it would be of higher quality. Finally, he realized that process-improvement's cyclical nature was not only with respect to "widgets," but also with respect to the way people think. In his prolific writing on the topic of Quality Management he laid out a framework for the practitioner, translating theory into practice.

TQM Failure Modes

While TQM initially began in manufacturing, the principles of management were found applicable across multiple domains. The transition from one company or domain to another was not always smooth, which led to an initial period of exuberance followed by failure. The authors of *Why TQM Fails* believe that "If there has been a failure, it is not one of philosophy; it is one of implementation." They classify failures into three phases; Startup, Alignment, and Integration. In each of these phases, the pitfalls are different and the reason or mode of failure may change:

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[6] W.E. Deming, *Quality, Productivity, and Competitive Position* (Cambridge, MA: MIT Center for Advanced Engineering, 1982).

1. In Startup, the primary drivers are related to lack of management commitment, poor timing and pacing, wasted education and training, and lack of short-term, bottom-line results.
2. In Alignment, the problems stem from organizational issues and TQM effectively becoming part of the bureaucracy, not part of culture.
3. In Integration, threats of a successful TQM-culture failure arise as leadership is not able to transfer power to the correct level. [7]

As TQM speaks to efficiency derived from empowerment at all levels of operation, it is diametrically opposed to a top-down management style, which creates conflict and potential for failure. Famously in the Toyota plant, while rarely used, every employee had the power to stop the production line. Brown, Hitchcock, and Willar note that in businesses where manufacturing is done more by machine than automation, TQM succeeds more easily than in those where it requires skilled labor. They do note that TQM has proven successful in other communities such as primary education, banks and other customer-service fields. Interestingly, their research found that the companies which are most successful in quality application are either startups or companies near death; this is likely due to commitment.[8]

In their research, Eisenstat, Spector and Beer found that general managers at the business-unit or plant level could construct a "critical path" to successful implementation. Their model of the critical path contained a sequence of overlapping steps. The difficulty they found was that timing mattered in when to start and stop efforts because important activities appropriate at one time are often counterproductive if implemented too early or too late; timing is everything in the management of change. They defined the six steps of the critical path:

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[7] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*
[8] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*, 57.

1. Mobilize commitment to change through joint diagnosis of business problems
2. Develop a shared vision of how to organize and manage for competitiveness.
3. Foster consensus for the new vision, competence to enact it, and cohesion to move it along.
4. Spread revitalization to all departments without pushing it from the top.
5. Institutionalize revitalization through formal policies, systems, and structures.
6. Monitor and adjust strategies in response to problems in the revitalization process.[9]

One difficulty in development and transmission of new ideas is the inability to deal with the time required for ideas to spread. When an individual makes a new discovery it is the act of self-discovery that imbues the experience or knowledge. The system must enable others to also achieve the same self-discovery to achieve buy in. Even if one leader implements a tool or technique and it works, it will take time for the system to enable others to do the same. The system is "short-circuited" if senior managers hawkishly watch for innovation to occur, and then try to force the same innovation across the system. It is better that senior managers watch for what environment produced the innovation and attempt to replicate the environment. If the environment of change can be replicated, leadership can trust that the system will continue to produce the same outputs. Unfortunately, as a rapid change is often desired, it is hard to overcome the temptation to copy success rather than the system for success.

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[9] Russell Eisenstat, Bert Spector, and Michael Beer, "Why Change Programs Don't Produce Change," *Harvard Business Review* November-Decemner 1990 Issue (November 1990).

AF TQM Authors

The DoD found appeal in a process which would enable a constant throughput with a reduced work force. For an organization realizing a reduction in size due to the post-Cold War drawdown, TQM seemed like a "silver bullet."[10] Officially the DoD mandated TQM in 1987-88, however, it is unclear exactly when the Air Force journey with the theory of TQM began. In June 1989, the Air Force Systems Command (AFSC) circulated TQM documentation.[11] According to Lt Col Barbara Kucharczyk of the Air War College, the Air Force officially and publicly pursued "quality-oriented" activities in 1991.[12] Officially, General Merrill A. McPeak, Air Force Chief of Staff, announced the birth of the Quality Air Force program three years after the DoD issued first guidance to move towards quality processes. In the early 1990s, the Air Force established Total Quality Air Force, led by The Air Force Quality Institute. This gave visibility and backing of senior leadership to the quality movement. While quality education and training were mandated by both the DoD and Air Force, it is unclear if buy-in was achieved by management and what levels of commitment various organizations made across the Air Force. However, it is clear that the establishment of the Air Force Quality Institute matched the theory of TQM, granting leadership support and a quality evaluation system (Unit Self Assessments and refocused Inspectors General), even including quality-oriented awards pushed from the top down.

Certainly elements of what would become TQM existed at the birth of the Air Force in 1947. During WWII, the vast scale of aircraft production, assisted by such industry titans as Ford, McNamara, and

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[10] Corporate Author: DoD, "DoD Total Quality Management Master Plan."
[11] Air Force Systems Center, "Total Quality Managment," June 1989, www.dtic.mil/dtic/tr/fulltext/u2/a229628.pdf.
[12] Barbara Kucharczyk, "Inculcating Quality Concepts In the U.S. Air Force: Right Music, Wrong Step" (Air War College, 1994), 1.

Sloan, implemented mass manufacturing and a small degree of quality control. Across several decades, the DoD and industry shared techniques and socialized quality concepts into the Air Force lexicon. The conditions in 1988-1991 clearly set the goal of TQM in the Air Force to, under a fixed set of resources, either increase the capacity of a system to perform a task or decrease the amount of resources required while maintaining a fixed output.[13] With a drawdown looming, equal capability with reduced resources was clearly the attractive element in TQM.

By 1995, the Air Force had come to terms with the implementation of TQM but the Quality Air Force (QAF) program was failing.[14] Officially, Air Force literature shifted to a partial rebranding of the program to attempt a reboot and gain new traction. In 2001, the Air Force again changed its posture to Air Force Smart Operations for the 21st Century (AFSO21).[15] However, AFSO21 and other process controls only contain the process control side of TQM theory without the management philosophy. This shift indicates that at the highest level Air Force leadership still saw value with the tools but implied if had lost faith in a cultural shift being possible. However, for functionality, the theory of TQM requires more than just processes control. The Air Force in 2017 yet again has changed its quality-assurance program to the Airmen Powered by Innovation Program.[16]

Creech's 5 Pillars

One of the Air Force's most outspoken proponents of quality processes in the 1980s and 1990s was General Bill Creech, the former commander of Air Force Tactical Air Command (TAC). After leaving the

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[13] Air Force Systems Center, "Total Quality Managment."
[14] Binshan Lin, "Air Force Total Quality Management: An Assessment of Its Effectiveness," *Total Quality Managment* 6, no. 3 (July 1995): 243–54, doi:10.1080/09544129550035413.
[15] AFSO21 citation: http://www.au.af.mil/au/awc/awcgate/af/afso21-fact-sheet.pdf
[16] http://www.af.mil/Portals/1/documents/cct/2016/CCT_18_FEB_2016.pdf

Air Force, Creech became an advocate, author, and consultant for quality in management.[17] He agreed with the view-point that the difference between classical mass manufacturing and total quality management was the element of quality. In classical mass manufacturing, large quantities of material are produced and the defects discarded, but no formal feedback loops are pushed to intentionally reduce such defects. Air Force processes following WWII aligned with mass manufacturing; but, as with American manufacturing, the concepts of cyclical quality improvement were not present at inception. Creech argued that an organization's structure and existing practices tend to disallow change. Creech argued that an organization needs four characteristics to succeed in change and thus reach higher efficiency in operations:

1. Maintain a quality mindset with respect to all processes
2. Be strongly humanistic; treat employees as valued assets
3. Make feasible empowerment at all levels
4. Apply holistically across the entire organization, not just "key" areas[18]

Creech believed that Total Quality Management suggests management or leadership built around the concept of quality. This requires a system or framework of quality to be the bedrock upon which all processes are centered. The resulting output is a lower defect rate, a higher throughput, or a decrease in cost. Only quality drives down cost, not cost-cutting measures.[19] His argument was that in the short run leadership can demand cost savings through reduction in overhead processes. For example, preventative maintenance, tracking statistics, upgrading hardware, extra training for personnel, and attempting new

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[17] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You.*
[18] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You.*
[19] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 173.

methods all place a drain of resources on a system. None of these activities saves time or money instantly, thus if resources are reduced people can appear to be maintaining productivity but cut corners over time. For a while, even years, it may appear like people are doing more with less, but this is false. Over the long run, the shaving of effort leads to defects and inefficiency in the process. Based on his life experience, Creech found that people are very good at "getting by." However, he found that just-good-enough in the long run led to very poorly performing systems. Thus, Creech centered his philosophy on Five Pillars or focal points to drive against this short-run thinking:

1. Product
2. Process
3. Leadership
4. Commitment
5. Organization

Moreover, Creech argued that by its nature, centralization "depressed the human spirit" whereas decentralization unleashed creativity and facilitated leadership. His observation was that as time progressed too many managers emerged. Organizations would be comprised of a bad "teeth" to "tail" ratio, too many managers and not enough work-force. Creech saw this as one of the ills of centralization.[20] From a theoretical standpoint, Creech also explained the impact of time through the analogy of an airplane autopilot. He saw the time lag between when an exogenous change occurs and when the system reacts to the external change. Not all systems, just as not all planes, respond as quickly as others. However, existing systems are stable just like a plane in flight. The military owes some success to rules which "idiot proof" the system, as

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[20] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 20–21.

military operations must be conducted by younger individuals often with low education or training in a time of war. Creech understood that it was the very "idiot proofing" of the system which led to success in one situation but would create inertial change in another. Thus, to implement quality and overturn existing practices, managers must wage an uphill battle to overcome forces desiring a return to the initial state of the system or the old way of doing business.[21]

Deming's 14 Points and the Air Force

In 1994, Air War College student Lt Col William Beck analyzed Deming's original 14 points to determine if they were universally applicable to the military in general and the Air Force in particular.[22] He concluded that the TQM approach, in its "pure form" as described by Deming, was not directly applicable to military organizations or the military environment. He concluded that disconnects occurred primarily with respect to five principles:

1. The military, while placing a large degree of trust in the enlisted force, may not be able to institute leadership the way Deming envisioned. There is not equality between the officer and enlisted ranks. This split might make a cultural change impossible, when an existing two-tiered system is an entrenched culture.

2. Military experience cannot always be directly trained, making it impossible to properly prepare "workers" for their job.

3. The concept of a customer and defining the customer may not be appropriate for all jobs, which makes development of metrics difficult.

4. Can quality be a concept in combat?

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[21] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.
[22] William Beck, "Total Quality...So What Is New?" (Air War College, 1994).

5. Can fear really be driven out with respect to all elements of the military job?[23]

Beck concluded that of Deming's 14 points, only nine were fully applicable and in use under the QAF program. The military, while often viewed as a top-down management style, places considerable trust and authority in the hands of the enlisted force. The structure of the Air Force, a pyramid of leadership, and containing a reserve force larger than its active duty component, presents a challenge in a high turnover rate of Airmen. Beck noted that his analysis could not fully negate any single point of Deming's, even a high turnover rate, thus the theory of TQM may be applicable to the military environment. In 1994, it appeared that the potential for an effective application of TQM was possible in the QAF approach. Moreover, he noted that, "It seems to confirm my assertion that not every area in the military environment…is within the domain of TQM application."[24]

A similar survey with a slightly more pessimistic outlook was performed by Lt Col Tomasz Kocon of the Polish Air Force, while at the U.S. Air War College. He agreed with the five disconnects found by Beck but surmised that the current leadership of the Air Force lacked the ability to modify TQM processes such that it could succeed in the Air Force. Mirroring Beck's opinion that 9 of 14 points proposed by Deming were directly applicable to the Air Force but the other five might not be applicable, he went a step further to call out the specific problem as he saw it: that command and control as a process is different from management. His general conclusion was that the culture of the Air Force, its education and mindset, lacked the ability to make the proper adjustments to specific conditions or environments. This systemic failure

[23] William Beck, "Total Quality…So What Is New?"
[24] William Beck, "Total Quality…So What Is New?", 25.

and inability of Air Force leadership would be the main reason limiting TQM implementation.[25]

It is possible that as an outsider looking in, Kocon was better able to analyze the system of the Air Force and the external policy of TQM it was seeking to apply. He believed that the Air Force was inappropriately treating TQM like a "panacea" or "silver bullet" and this was the primary cause for its inability to "catch." While making a point by point comparison of TQM, he went beyond Beck's work to make a systemic argument. This work implied that TQM would fail as implemented because the leaders produced by the Air Force system could not be the same as those who could effectively implement TQM.

Both authors directly noted that experience resides within the individual performing a process or task, and that acquiring military knowledge and the value of military knowledge may not be equal to that in the civilian world. Beck rationalized that there are military activities that are heuristically similar to those in the civilian world, calling them "safe" fields. The areas of support, logistics and maintenance are such fields. However, he noted that even within these functions, which theoretically could be performed by contractors, the system of military organization may make implementation incompatible. Creech wrote that TQM does not necessarily require individuals in an organization to be subordinate to centrally controlled leadership. Centralization, while useful in economies of scale, is a barrier to the feedback required to instill quality, which kills innovation. [26] It must also be noted that through the lens of Beck, when Creech led Tactical Air Command (TAC), it would have been considered a "safe" area for TQM. Where safe implies not physical security but close alignment to civilian manufacturing;

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[25] Tomasz Kocon, "Quality Air Force and Deming's Fourteen Points" (Air War College, 1994), 27.

[26] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 65.

airfields closely align with easily repeatable processes. The concept of an airfield, or airport, is mirrored in the civilian world. Moreover, the maintenance, customer, system boundary, and metrics associated with flight are more easily defined than other military activities. Most importantly, the repeatable process occurs on a very short time interval; lessons can be tested and incorporated day-to-day.

However, a military airfield is still more difficult to support with TQM-style management compared to a civilian airport for several reasons. Consider the military requirement where a plane must be launched for a mission. The cost of missing a sortie may be different than the cost of missing a civilian transportation flight. The authority and judgement to miss a delivery versus a sortie may reside at a different level. In TQM it may be the best practice to miss flights, or offer fewer services for a time, to "get things right." Obtaining the time and space while implementing TQM may not be the best practice in a military setting as one cannot trade a loss in national security in the manner that an airline would trade lost revenue when implementing TQM.

Another issue was noted by Creech when he wrote that leaders fear decentralization as it implies loss of direct control and decision-making. The fear is a loss of visibility into problems, causes, and sources, "you don't know what you don't know."[27] Decentralization can be at odds with the very framework or structure of the military, thus unintended consequences may occur when attempting to implement TQM and a cultural change. Creech wrote that the way to maintain control in decentralization is to track outputs, and that a team concept breeds ownership. Creech pointed out a truth that the loss of visibility in decentralization is not really a loss at all because as a leader one could never have visibility into some issues; it is the loss of the illusion of

27 Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 239.

control. In shifting to a control-based-outputs management, the leader may actually gain greater and more meaningful visibility than with centralized control. The AF can and does breed ownership but with a different motivation that the civilian sector. In decentralizing, control is achieved by viewing the outputs of a process and then taking action where they fail. If a leader has the proper output, that leader inherently has control. The hard part is getting visibility into the outputs. [28]

In Kucharczyk's experience, the Air Force initiated its quality education efforts by focusing on Total Quality Management (TQM), as outlined by Deming, the acknowledged "Father of TQM". Students in the Air War College elective Executive Quality Leadership were given *The Deming Management Method* by Mary Walton as part of their course materials. However, Kucharczyk noted that Air Force education violated the first principle; it failed to establish relationships between old-system and the new TQM system to be adopted in this course. One cannot change the existing system to a new system without first understanding the existing way of business. Kucharczyk argued that if the Air Force could not provide proper training to its senior leadership in a controlled environment such as the Air War College, what was the level of training in units. Furthermore, reading and discussing a single book would barely qualify as education or training on a TQM system as it lacks implementation on a specific system or repeatable process. To be effective, the students would need to go back to their units, implement ideas, iterate on them and then receive further consultation.

[28] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 312.

TQM in the Air Force—Existing Case Studies and Results

TQM in the Aeronautical Systems Center

The issue of repeatable processes in acquisition System Program Offices (SPO) is a contentious one. The mission set of SPOs is one of management and repeatable processes. Thus, to the outside observer it may appear that SPOs would be a perfect opportunity for a properly tailored TQM-style process. However, the results in the early 1990s were mixed, leading to questions about systemic failures or deficiencies stemming from differences in leadership commitment. The results of one case study performed by Lt Col Richard Hassen[29] on the 4950th Test Wing maintenance complex and another performed by Capt Mark Caudle[30] on the Aeronautical Systems Division (ASD) SPO grant some interesting insights.

Hassen found that when forced into a geographic move, the 4950th Test Wing Maintenance Complex implemented a total-quality-based organizational redesign as a strategy for achieving a smooth transfer of function. Upfront, leadership realized that the move would likely have a large impact on mission readiness. The threats to reduction in number of sorties completed and the disruption that moving from one location to another would bring were apparent. Moreover, it was known that corporate knowledge could be lost with people who would not be completing the move; experience lives in the minds of people.[31] Leadership also noted that this move represented an opportunity, as it came with additional resources and a grace period where an expectation

[29] Richard Hassan, "Redesigning Organizations: A Case Study of the Air Force 4950th Test Wing Maintenance Complex Total Quality-Based Organizational Redesign" (Redesigning Organizations: A Case Study of the Air Force 4950th Test Wing Maintenance Complex Total Quality-Based Organizational Redesign, n.d.).
[30] Mark Caudle, "An Analysis of Total Quality Management in Aeronautical Systems Division" (Thesis, AFIT, 1992), 4–5.
[31] Hassan, "Redesigning Organizations: A Case Study of the Air Force 4950th Test Wing Maintenance Complex Total Quality-Based Organizational Redesign."

of reduced capability would allow for process improvement. Moreover, the geographic move came with the ability for cultural adjustment and a ground-up reconstruction of new operations. Hassen concluded that leadership was "smart" and committed. They invested heavily in initial training, possessed a "get-it-done" attitude and had sufficient resources in manpower. The context forced the construction of a new culture and the new location was able to build up over a time period of six to eight months before full operations were transferred.

Conversely, Caudle found that ASD's training program, while well-grounded in group dynamics and quality-improvement theory, provided only elementary tools. His research found no evidence that more advanced statistical training was conducted. Thus, the groundwork was laid, but the training to capitalize was never given.[32] This is a worst-case situation as investment was made, but that effort was effectively a waste of time and money as it was insufficient to payback. One might view such behavior as a lack of commitment by leadership. The question becomes: did local leadership implement only the minimum needed to meet a requirement from on high, or did they possess insufficient training on the real requirements for obtaining payback on TQM process? In his interviews, Caudle noted that it was a widely held belief that there was little upper-management support for delaying work to ensure a quality product. This highlights the difficulty in pushing a change in culture; when suspenses and other pressures are brought to bear, many claim that they feel pressure to put out the fire, regardless of the long-term implications. Caudle's research on ASD found only a handful of surveys or other measurement instruments. The existence of so few artifacts indicates that the organization was not tracking metrics. These are the exact useable metrics that leadership would have used to track

[32] Caudle, "An Analysis of Total Quality Management in Aeronautical Systems Division." 5-2

progress across organizational lines or within individual organizations to ensure a smooth transition to TQM.[33]

Working with the available documentation, Caudle also concluded that the issue of a merit-rating system was likely to emerge. In analysis Caudle found that ASD's training clearly highlighted high-performing individuals, not groups. The problem of systemic Air Force requirement for "racking and stacking" individuals seems to have appeared and hindered teamwork in ASD.

System Program Office Study:

Col Gary Delaney and Lt Col Michael Prowse performed a study comparing the System Program Office (SPO) and the theory of TQM. [34] They noted a huge difficulty determining appropriate metrics due to the complexity associated with system-boundary changes. If the process includes contractors, then not all processes may be controlled by the Air Force or may be heavily influenced by exogenous factors.[35] Even more complicated, metrics now had a greater potential to incentivize the wrong behavior. To assist in their analysis on the impact of metrics, Deming's 14 points, and system boundary, Delaney and Prowse tailored the TQM process to the SPO. Figure 1 shows how Delaney and Prowse viewed TQM as a policy applied to a system.

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[33] Caudle, "An Analysis of Total Quality Management in Aeronautical Systems Division.", 5–3.

[34] Gary Delaney and Michael Prowse, "Total Quality Management: Will It Work in the System Program Office?" (Air War College, 1990).

[35] Gary Delaney and Michael Prowse, "Total Quality Management: Will It Work in the System Program Office?", 71.

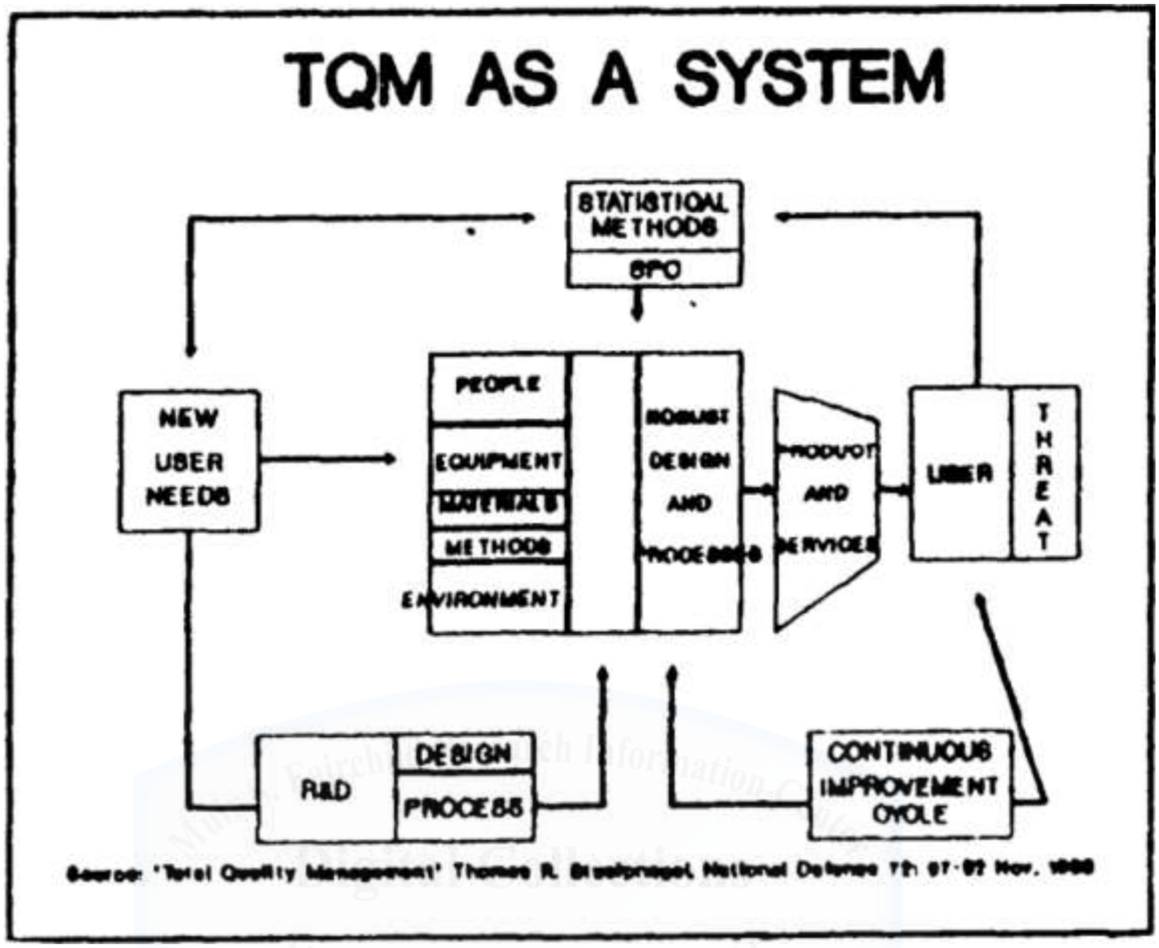

Figure 1: Total Quality Management is a closed loop system

Source: Thomas Stuelpnagel, "Total Quality Management," *National Defense* 72 (November 1988): 57–62.

Taken from the TQM management guide, Delaney and Prowse drew inspiration from the feedback cycle present in the process. Figure 2 shows how the DoD envisioned a TQM process - data feeding into analysis and action generating new data.

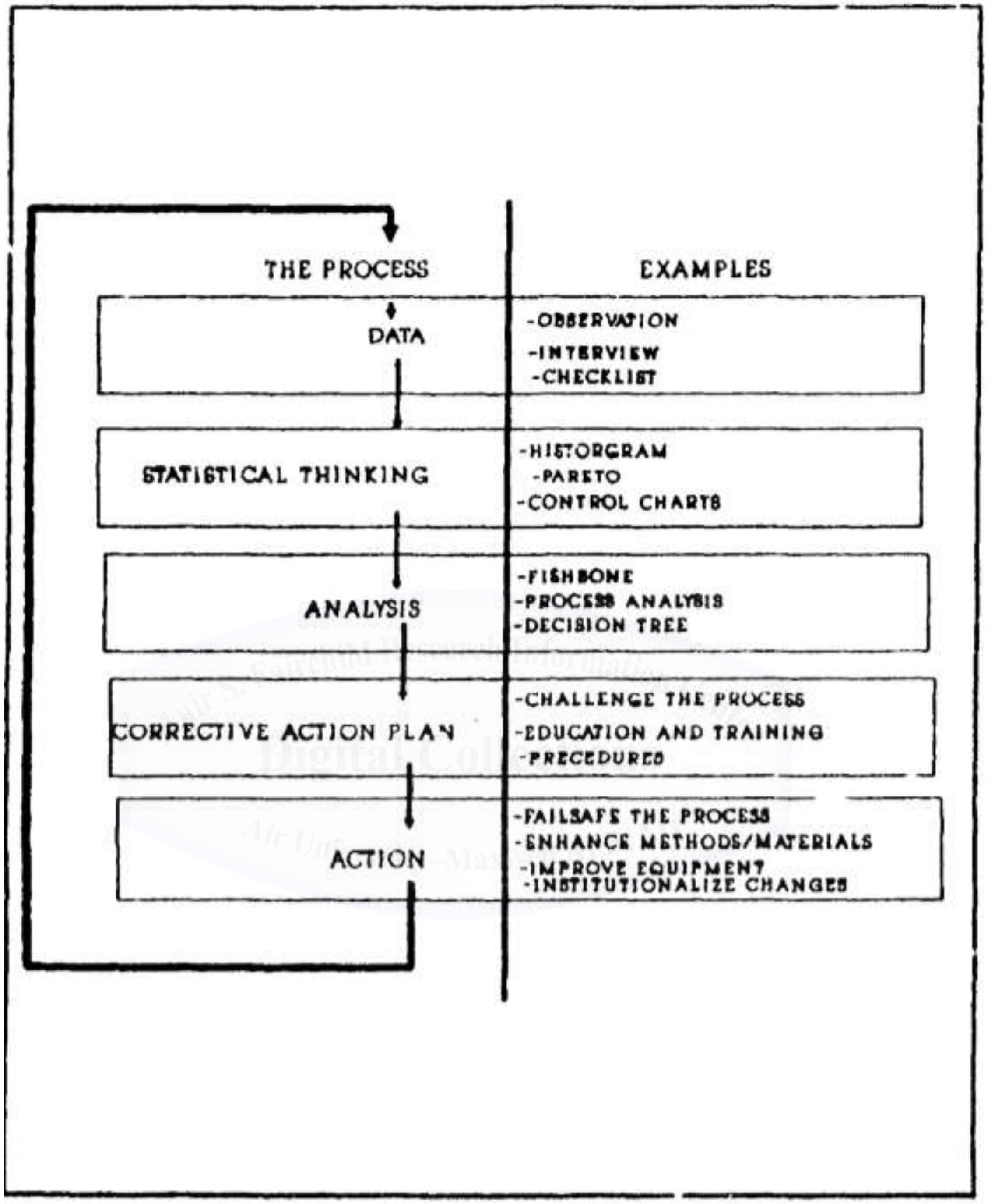

Figure [illegible] Improvement Cycle.
Source: DoD 500.51G, Total Quality Management Guide.

Figure 2: Improvement Cycle Per DoD 500.51G

Source: Delaney and Prowse, "Total Quality Management"

Having performed the system-boundary analysis, and having tailored TQM to the SPO, Delaney and Prose were optimistic in 1990 that the Air Force may have learned some lessons about placing quality into process. Echoing Creech, they noted that the classic "production base" approach indicates that increased quality means increased production cost, time, and an expanded inspection system to ensure quality.[36] They believed that through proper application of the cyclical process diagramed above that the Air Force may embrace the concept that providing a quality product or service costs less than associated costs of rework. Further, differing from other authors' interpretations about fear, they believed that the SPO can be compliant with Deming's eighth principle, to "drive out fear" as well as his ninth to "break down barriers between departments." As the SPO is not involved in combat activities, they believed fear is in line with Deming's original point about workers being able to bring problems to leadership. They believed that the culture of the SPO would be amenable to removing fear. This creates the question of why their systemic analysis was wrong, what was missing, or what assumptions were incorrect? Later in this chapter the element of time or the speed with which the loops flow in the above diagrams will be identified as the missing component in their analysis of the SPO.

Schedule Metrics in the Aeronautical Systems Center

The problem of proper metrics is well articulated in Hayes and Miller's work on metrics inside the Aeronautical Systems Center (ASC).[37] The first difficulty in determining metrics is noted to be the overhead time required to create and then evaluate metrics and their respective performance. The ASC team believed that one hour was required to properly process each metric. In the study, metrics were compared on a

[36] Gary Delaney and Michael Prowse, "Total Quality Management: Will It Work in the System Program Office?", 42.
[37] Robert Hayes and Lawrence Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center" (Air Force Institute of Technology, 1992).

scale indicating if the metric contributed to continual process improvement against how well the metric drove the behavior. The finding echoed an earlier difficulty of applying TQM to a military structure that the "customer" was often hard to define. Moreover, as the repeatable process of creating requests for proposals makes it hard to define what a good proposal is. The time in between creating a proposal, evaluating bids and then understanding the impact of the flaws in the contract is on the order of years. Thus, no feedback on the actual value of the work could be constructed. Moreover, the average timeline for a request-for-proposal process was 180 days. This implies that the time for one learning cycle was: 180 days, plus the time to consider what could be done differently, plus the time for the next 180 days RFP to be completed with the new procedures and finally the time to analyze if the changes were positives or negatives on the process. At a minimum this would mean the average learning cycle was longer than a year. While the SPO considered 180 days a "reasonable timeline," for completing work, often an additional complication arose when attempting to reduce cycle times. It was found that by attempting to meet time deadlines contractors were able to negotiate from a position of strength. Contractors, knowing the government wanted to complete the contract quickly, could play for time and increase pressure on the SPO to agree to their terms. Beyond this, it should be noted that a process cycle time of 180 days is a long timeline to flow back experience and may contribute to less trust in "stale" metrics.[38]

The uniqueness of the work in creating Request for Proposals (RFPs) inside the SPO and attempts to quantify the goodness of speed or accuracy of the RFP generation is also difficult, as each one may be

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[38] Robert Hayes and Lawrence Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center", 4–14.

unique. This again leads to distrust in the metrics.[39] It was found those in ASC would inherently push towards quantity, not quality, the exact opposite of what is desired by TQM process.[40] It is easy to track quantity but understanding quality in contracting is very difficult. The difficulty in linking time metrics to contractor activities is faster does not always equal better and it may incentivize on time products of low quality. Hayes and Miller list the example of a casher checking out food at a grocery store. In this example it is a fair conclusion that the average scan time of each item is a net positive; the more scans per hour or the number of scans per time unit is an improvement. However, if a contract modification time is measured the same may not hold true. If a contract modification is required then negotiation with another party must occur. Terms of the negotiation and the legality of the proposed modifications must also be reviewed; faster might place more risk on the government. Risk in contractual negotiations is subjective, not objective, which is exactly the opposite of what metrics need to be for TQM to function. Moreover, the time between decision and the risk posture being uncovered and the incurring of the risk may be on such a long time scale that it cannot be fit into a TQM process. Thus, the inherent nature of TQM is hard to understand with respect to acquisitions.

The conclusion of their work was broken down in 8 final points:

1. A single metric may need to be integrated with others to be truly effective.
2. Metrics can lead to sub-optimization in the functional areas within a SPO.
3. Behaviors that focus on exploring and improving processes promote continuous improvement. Behaviors that focus on goals, quotas, and the end result usually does not lead to continuous improvement.

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[39] Robert Hayes and Lawrence Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center", 4–24.

[40] Robert Hayes and Lawrence Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center", 4–18.

4. The field of metrics is a challenging area of study because of the unique features of not-for-profit organizations.
5. In order to be fully understood and correctly used, metrics need to be coupled with an objective.
6. If the metric focuses on an activity the SPO has no control over, it shouldn't be used.
7. Too many metrics can be detrimental to the program office.
8. SPOs should consider using Group Support Systems (GSS) to develop their own internal metrics. [41]

The fact that ASC went to such efforts to construct proper metrics and internally understood the difficulty of tailoring a TQM process seems to indicate that leadership supported quality efforts. The act of reviewing metrics is actually an indicator of TQM success. The breakdown in ASC seems to have arisen as knowledge is lost or fails to make it into the next generation of people handling the process. Of note, the ISO 9001 series guidance rates the people in the process as the key to what level of proficiency an organization merits, stating that at minimum of two years MUST elapse between re-rating an organization.[42] The data missing from the ASC case study is when the process improved and when it failed. According to the ISO 9001 guidance there should have been periodic evaluations approximately every two years to determine if the organization was moving up the "proficiency" ladder. A proper implementation of TQM in QAF should have produced thousands of reports across the Air Force rating the progress of each unit as it implemented QAF. These reports would document the types of units and the rate at which they were able to comply with QAF. Being able to examine which types of units adopted faster than others would be

[41] Robert Hayes and Lawrence Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center", 5–1.
[42] International Organization for Standardization, "ISO 9001:2015: How to Use It" (International Organization for Standardization, 2015), http://www.iso.org/iso/iso_9001-2015_-_how_to_use_it.pdf.

valuable data to this research. Such data would enable to extract the impact of context on success, sadly it does not exist.

Air Force Summary

The opinions and findings of the authors in this section is striking when compared to the historical results of the Air Force's TQM implementation. The fears and pitfalls present in industry and TQM theory are exactly borne out in the Air Force.[43] The Air Force creates training programs that target competence or technical skill, but rarely target a change in patterns of coordination. The industry authors note that sometimes the result of good corporate training programs frequently leads to frustration[44] when employees return to the job and see their newly acquired skills go to waste as one individual's knowledge is unable to push quality initiatives in an organization that is not committed to cultural change. This leads to people viewing training as a waste of time. Over time, this creates a culture which undermines leadership's commitment to change and further entrenches the existing culture, making change even more difficult in the future; people hunker down for the "storm" and figure they can wait out the fad.

System Dynamics

The theory of TQM process improvement operates upon multiple feedback cycles. Thus to model TQM, a tool capable of examining change over time is required to describe an iterative and causally linked process. One might describe a situation where action A leads to B, B to C and C back to A. This creates the basic concept of a causal loop.[45] Such a simple loop can be understood easily, but what if C leads to D which

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[43] Lin, "Air Force Total Quality Management: An Assessment of Its Effectiveness."
[44] Eisenstat, Spector, and Beer, "Why Change Programs Don't Produce Change."
[45] In System Dyanmics the modeler is not starting that causality has been found, rather they are proposing a causal relationship that they believe might exist. It is thought he process of proposing and testing different causal interactions, based on an epistemological view of the world, that a model is constructed.

leads to E and then E leads to C. To further complicate matters what if E leads to A. Such an arrangement could be drawn as depicted in Figure 3 however, understanding how this relationship might change the operation of the system over time is impossible for human minds to predict.

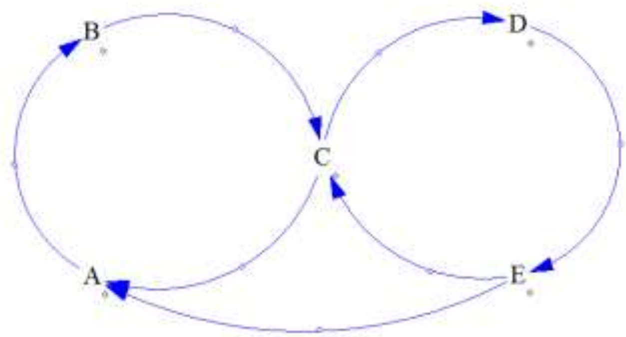

Figure 3: Example Causal Loop Diagram
Source: Author's Original Work

Dr. Jay Forrester wanted to understand how human performance might change in a dynamic environment. In the late 1950s, Forrester created the field of System Dynamics to assist in understanding such feedback processes. He then spent his life improving upon and expanding the System Dynamics methodology.[46] To enable such a research methodology, Forrester based his method on the same mathematics of another emerging field, control theory. System Dynamics classifies actions in a system into two categories; stock and flows. Stocks function as stores of memory over time, how much of a thing is present: people, water, widgets etc. Flows represent the rate of change over time, or how fast is a stock increasing or decreasing at the present. Most System Dynamics models also possess intermediate variables used to simplify calculations and make the operations of a system easier to understand to the user. Arrows connecting variables are usually labeled

[46] Thomas Hughes, *Rescuing Prometheus:Four Monumental Projects That Changed the Modern World*, Reprint Edition (Vintage, 2000), 35.

with a + or a – sign. The + indicates a positive correlation between the variables and the – represents a negative correlation; if no sign is labeled then the relationship is ambiguous or may shift based upon context.

While many authors have proposed System Dynamics Method they generally work a model-construction process similar to that currently utilized by the Sloan School of Management, which is a four-step process based on initial work by Dr. Jorgen Randers in the 1980s: [47]

1. Define the problem: identify variables, cluster like concepts
2. Diagram Causality: Identify variables, direction of causality, create stock and flow diagrams
3. Simulate deductive model: test individual loops, ensure trends and direction match expectation and historical reality, link individual loops into a combined model.
4. Inductively tune model: use historical reference modes to match model outputs, use statistical tools to validate model and capture error [48]

This thesis will stop after the third deductive step as deductive reasoning is considered sufficient for academic purpose as noted by the system dynamics society.[49] Moreover, as this thesis is constructed as an abstract model, inductively tuning such a model would have meaning only if sufficient real-world data could be gathered from a specific unit. This might be a worthwhile consultation exercise but is beyond the scope of this work.

System Dynamics in a Case Study Methodology

Dr. Robert Yin's work on case studies and the case study as a methodology for social-technical inquiry, notes the importance of collecting data and information from multiple sources to aid in the

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[47] Jorgen Randers, *Elements of the System Dynamics Model* (Portland, OR: Productivity Press, 1980).
[48] Albin Stephanie and Jay Forrester, "Building a System Dynamics Model" (Cambridge: Massachusetts Institute of Technology, 1997).
[49] Corporate Author: System Dynamics Society, "System Dynamics for Academia," *System Dynamics Society*, 2014, http://www.systemdynamics.org/sd-for-academia/.

identification and analysis of trends and to enable predictions of future trends.[50] This is a very similar to the preferred SD methodology outlined by the System Dynamics Society.[51] Yin lists six primary sources of evidence: documentation, archival records, interviews, direct observation, participant observation and physical artifacts. For this thesis documentation, archival records, and physical artifacts are used. As a secondary source, interview data is also ascribed from the broad body of literature on TQM. Deductive System Dynamics can be utilized within the context of a case study as a way to increase the validity of the narrative argument. A simulated model is derived from causal statements if the model is able to match the trend and inflection predicted by a narrative argument or theory then it lends credibility to the theory. While it may be impossible to prove causality, a mathematical model can show that an idea is at least plausible lending weight to a theory.

System Dynamics—Molecules of Structures

Dr. Jim Hines, an expert in System Dynamics modeling, outlined basic structures for SD modeling in his work titled "Molecules of Structure." Within the SD method, all basic ideas (experience, efficiency, pipelines) should be constructed using basic "molecules of structure." His contribution to the field was in documenting and outlining the utility of re-using proven mathematical structures to assists with validating a model. For example, manufacturing a pipeline is a common structure. Figure 4, taken from Dr. Hines' work, displays a basic structure which can model a pipeline which responds to external conditions; the math for all pipeline-based models can gain validity from following this generic set of coupled partial-differential equations.[52]

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[50] Robert Yin, *Case Study Research: Design and Methods*, 5th ed. (Thousand Oaks, CA, 2014).
[51] Corporate Author: System Dynamics Society, "System Dynamics for Academia."
[52] Jim Hines, "Molecules of Structure" (Massachusetts Institute of Technology, 2005).

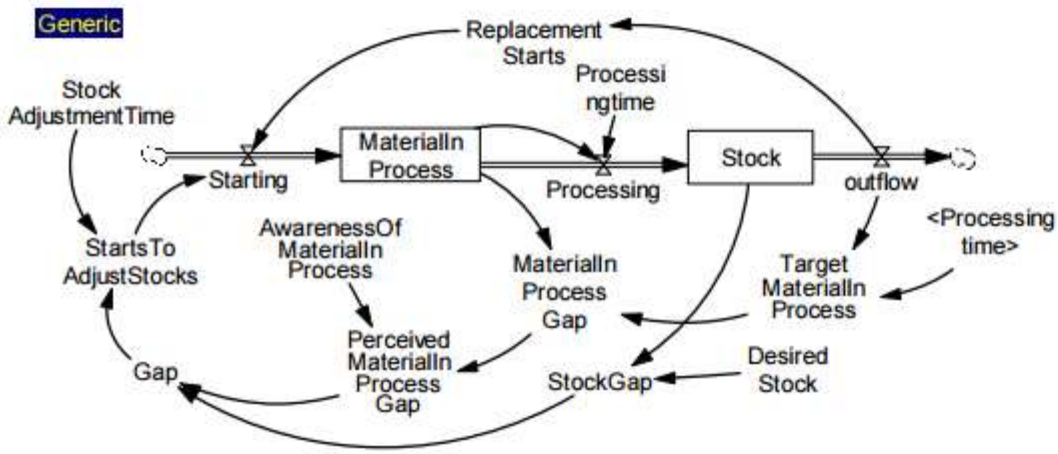

Figure 4: Generic Pipeline with Correction to Changing Outflow developed by Dr. Hines

Source: Hines, "Molecules of Structure"

By implementing this model design, in a pipeline based system dynamics model, a reasonable assurance is made of a proper SD representation of a pipeline, and that it will function as a correct component in a model.[53] In Figure 4, the two SD stocks of "Material In-Processing" and "Stock" can be seen. The three arrows labeled "Starting," "Processing" and "Outflow" are the flows in the model. All the other remaining variables are intermediate variables which tune and represent the relationship in the model.

Work Harder Vs. Work Smarter

The concept of doing a task right the first time is taught as common wisdom. However, in all aspects of life people cut corners to save time. Sometimes time is saved, but other times the corners cut come back to haunt and actually lead to more work or rework required than if the job had been correctly completed the first time. Within the context of manufacturing, the idea of quality and its relationship has been investigated in this literature review; TQM is the policy of building a

[53] There is no need to reinvent the wheel and this thesis will implement existing molecules of structure; it is the unique configuration which will grant insight into TQM.

culture of doing it right and benefiting over the long run by driving out inefficiency. Now the task of converting the idea of either spending resources to learn how to do a task right (TQM) versus just doing a task (classical mass production) must be simulated. Dr. John Sterman, the Jay W. Forrester Professor of Management at the MIT Sloan School of Management and the Director of MIT's System Dynamics Group, converted Deming's theory into the concept of resources being divided among tasks.[54] This created a mathematical model for how resources could be allocated among tasks. The basic concept of "Total Resources" being divided between two activities "Resources to Production" and "Resources to Improvement" is clearly seen in Dr. Bradley Morrison's diagram in Figure 5.

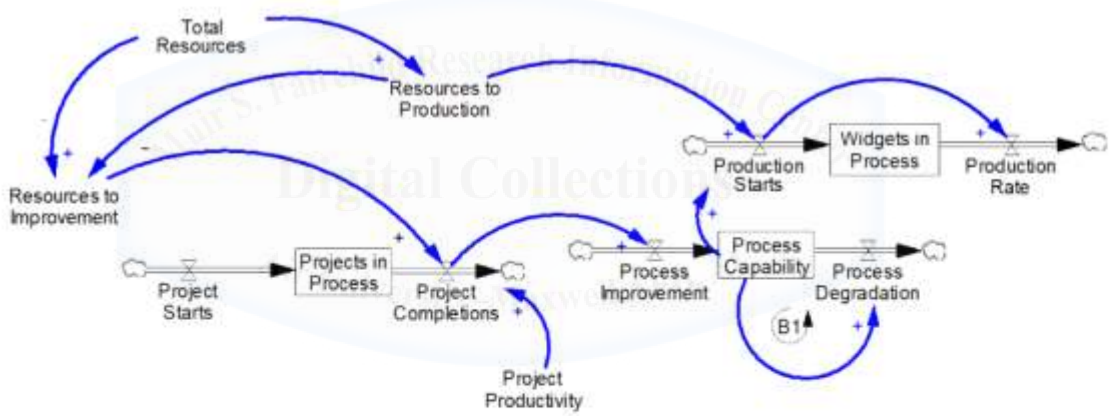

Figure 5: Morrison's Work Harder Vs. Work Smarter Balance Diagram
Source: Morrison, "Implementation as Learning: An Extension of Learning Curve Theory"

Expanding upon earlier work, Dr. Morrison included the idea of changing policy from and existing policy to a new policy. This is a model that can now represent one basic idea of applying TQM (a policy) to an existing system. Beyond this, various authors have demonstrated several

[54] J. D. Sterman, N.P. Repenning, and et al., "Unanticipated Side Effects of Successful Quality Programs: Exploring a Paradox of Organizational Improvement," *Management Science* 43, no. 4 (1997): 503–21.

approaches for encoding "soft systems," or ideas which cannot physically be measured. For example, experience is a concept but it, unlike hours or money, is not something that can be seen or touched. By implementing learning-curve theory a SD structure, like that seen in Morrison's work, can depict experience as a store.[55] One critical contribution was the decision to utilize an S-Curve as a representation of learning theory. Thus, the effect of learning when coupled with a new process such as TQM can be deductively analyzed. Figure 6 builds upon Figure 5 by encoding a stock labeled "Experience with new methods." This model states that over time new methods build change and impact the "Productivity." Over time this increases the rate of "Project Completions" as completions is the number of projects in process multiplied by the productivity. Thus, the closer to one (1) that the productivity reaches the closer to perfect, defect free, construction the system becomes. Through the lens of TQM all process-improvement activities are the quality projects being implemented and iterated upon inside the unit. Over time, all else being equal, the successful completion of quality projects leads to a higher production rate of widgets. This model simulates Gen Creech's quote that "Quality drives down cost, not cost cutting measures."[56] Once a project is completed, the benefit is cumulative with other projects. However, process improvement is not permanent. Looking at the stock of "experience with new methods" the flows of "process improvement" and "process degradation" cause experience to change over time; the system can learn and forget. The rate of learning and forgetting will be dependent on the people and other systemic factors.

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[55] Bradley Morrison, "Implementation as Learning: An Extension of Learning Curve Theory" (Waltham, MA: Brandeis University International Business School, 2008).
[56] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 173.

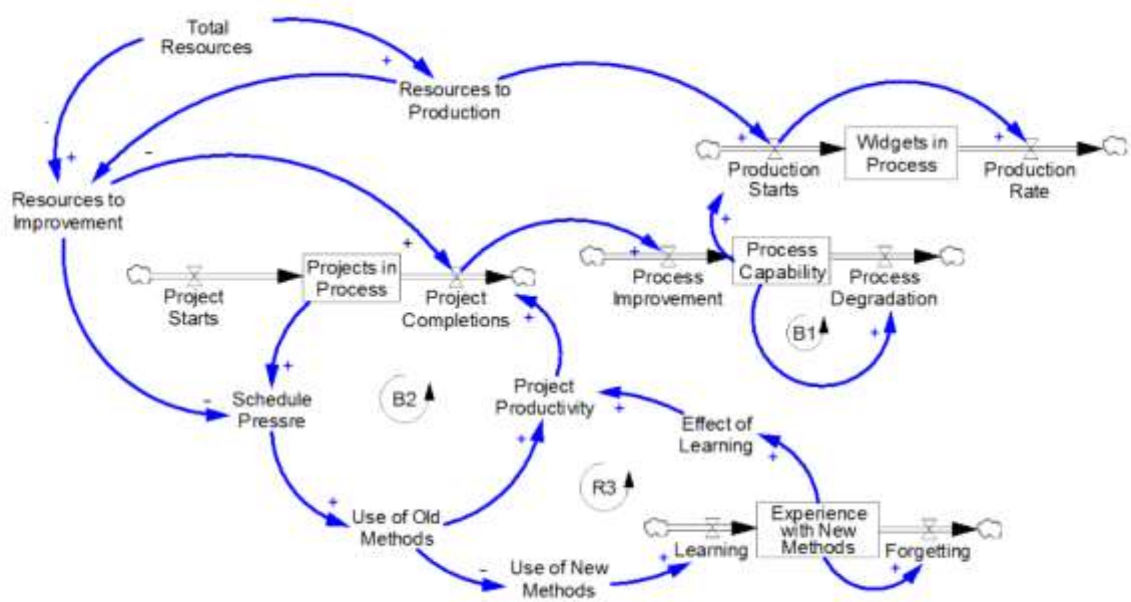

Figure 6: Dr. Morrison's diagram of resource allocation, pipeline production, experience and capacity

Source: Morrison, "Implementation as Learning: An Extension of Learning Curve Theory"

In the next section, the abstract model of Figure 6 will be expanded upon and discussed in further detail. The loops will be recast into the language of Air Force operations and applied to the concept of flight line operations. The theories and concepts gathered in the literature review will be used to justify the implementation of Dr. Morrision's work and other molecules of structure as the appropriate way to represent the TQM policy when applied to the Air Force.

Summary

TQM has been identified as an iterative process which self-reinforces over time.[57] Initially TQM concepts grew out of manufacturing. Over time, TQM has expanded to other domains and markets. The term quality has grown to incorporate concepts such as re-work, yield and efficiency. While quality control is a critical component of TQM-style

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[57] Eisenstat, Spector, and Beer, "Why Change Programs Don't Produce Change."

implementations, TQM extends to a holistic view across management. While much literature on the success and failures of TQM focuses on the role of leadership in implementation, several key system concepts can be consolidated based on the findings of the authors cited in this literature review:

1. There exists a closed system of people delivering value to a customer[58] [59]

2. An existing system is likely in balance and there are systemic reasons why change may be resisted.[60]

3. TQM is a policy applied to the system to bring change to the system where,[61]

4. The goal of any TQM policy is cost savings or increased throughput derived by higher efficiency, greater yield or reduced re-work.[62]

5. Experience with process resides within the individual, and experience is gained by working with a policy. [63] [64]

6. Decentralization is desired to empower the front line workforce to create and implement new ideals, the success or failure of such ideas require, [65]

7. Leadership to initially support the new policy until it "catches" and, [66]

8. There is a time lag between change and the result during which, [67]

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58 Deming, *Quality, Productivity, and Competitive Position.*
59 Thomas Stuelpnagel, "Total Quality Management," *National Defense* 72 (November 1988): 57–62.
60 Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.
61 Eisenstat, Spector, and Beer, "Why Change Programs Don't Produce Change."
62 Juran, *Juran's Quality Handbook.*
63 Beck, "Total Quality...So What Is New?"
64 Hassan, "Redesigning Organizations: A Case Study of the Air Force 4950th Test Wing Maintenance Complex Total Quality-Based Organizational Redesign."
65 Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You.*
66 Corporate Author: DoD, "DoD Total Quality Management Master Plan."
67 Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.

9. Leadership must support through manpower and funding[68]

With respect to the Air Force, TQM may or may not properly align for systematic reasons, but none seems impossible to prevent TQM providing value to the Air Force.[69] While many case studies were conducted in the early 1990s, enthusiasm tapered off by 1994. It is unclear if initial gains and enthusiasm came from true TQM change in culture or only from the education of quality-process concepts. What is clear is that TQM did not "catch" across the Air Force or DoD. Based on this literature review and the writings cited in this literature review, any Air Force leader seeking to implement TQM would need to consider the context of:

1. A centralized military structure may fight against decentralization, the barriers of structure (officer/enlisted) may lead to some teaming arrangements becoming impossible[70]
2. Normative behaviors which resist change are present in all organizations, but they may be especially strong in some military units such as,[71]
3. Low support for product delay or military requirements that cannot be delayed.[72][73]
4. Gaining Experience for some military activities may be difficult and,[74]
5. The turnover rate of the military may erode experience before it can be obtained.

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68 Kent Sibyl, "Planning and Implementing Total Quality Management in an Air Force Service Organization: A Case Study" (Air Force Institute of Technology, 1990), 1.
69 At least no arguments have been made that TQM is not flexible enough to at least deliver a value additive process to all levels of management in the military.
70 Delaney and Prowse, "Total Quality Management: Will It Work in the System Program Office?"
71 Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.
72 Caudle, "An Analysis of Total Quality Management in Aeronautical Systems Division," 5–3.
73 Beck, "Total Quality...So What Is New?"
74 Beck, "Total Quality...So What Is New?".; Kocon, "Quality Air Force and Deming's Fourteen Points."

6. Defining a customer and thus the appropriate metrics may be difficult.[75] [76]

7. Large systems with external control over processes which may lead to inefficiently sized units where,[77]

8. Metrics incentivizing the wrong behavior and inability to,[78]

9. Own or define a process due to contract functions with large variation[79]

Due to the time-based nature of System Dynamics and the existing body of research by Morrison, a System Dynamics model may offer valuable insights into implementation of TQM in the Air Force. The work in this thesis will now simulate experience, policy and changes in efficiency. This research will be grounded in the theory of TQM and its implementation in the Air Force as discovered in this Literature Review.

[75] Hayes and Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center," 4–18.
[76] Sibyl, "Planning and Implementing Total Quality Management in an Air Force Service Organization: A Case Study," 4.
[77] Delaney and Prowse, "Total Quality Management: Will It Work in the System Program Office?," 71.
[78] Hayes and Miller, "An Evaluation of Schedule Metrics Used Within Aeronautical Systems Center," 4–24.
[79] Delaney and Prowse, "Total Quality Management: Will It Work in the System Program Office?"

Chapter 3

Methodology

This section implements a system dynamics (SD) method as described in the Literature Review. The summary section in the Literature Review fulfills the first step of the SD method by identifying and clustering similar concepts. Since TQM operates as a policy applied to a system, SD is an appropriate method to increase the validity of a systemic analysis within a case-study methodology. Additionally, the research and historical implementation of TQM onto various Air Force operations strongly implies that the Air Force viewed TQM as a viable set of policies for continual process improvement. As SD has been demonstrated to be an appropriate modeling approach for simulating process improvement, this work will implement an SD model to better understand TQM in the Air Force.

Per SD best practices and to make this work approachable to Air Force personnel, terms will be cast in the language of Air Force operations. To abstract the concept of an Air Force system, and the implementation of TQM onto that system, the context of preparing and flying sorties will be used. However, as this work is abstract and theoretical, its value is not to understanding a single implementation but to understanding how implementation functions over time, extracting the impact of policy. System Dynamics as an abstract modeling approach seeks to understand trends over time. Again, per best practice, the language of such trends should be that of Air Force operations, however, this does not demand using complicated jargon. Structures developed must be approachable and easily understood.

As this work is deductive, the individual values used need not matter, but the ideas themselves must resonate (e.g., the exact number of sorties flown or the number of hours to prepare a sortie need not be precise, but their value and units must appear logical or believable to Air Force personnel). Moreover, in the SD method not every concept must be included in the analysis. A model can be considered sufficient if it communicates the necessary ideas while not overly complicating the behavior. Throughout the discussion, exclusion of various concepts will be detailed and justified. Typically a concept can be excluded or clustered if it will not change the direction or inflection of a causal loop. Thus, this investigation is interested in two types of change: change in direction or inflection and changes in rate of change.

Overview of Methodology Section

In this section the core elements of a system, representing a work pipeline with a repeatable policy and output dependent on efficiency, are constructed. Per the literature, the following concepts were determined to be a minimal set for inclusion in the model:

- A work pipeline with task completion
- The idea of efficiency or re-work,
- Experience
- Resources
    - A workforce
    - Workforce behavior
- The idea of applying policy to this system
    - Reactions to policy

Each of these concepts must be turned into molecules of structure; small pieces of code sufficient for testing and understanding one concept.[1] In each of the following sub-sections a simple model (molecule of structure) will be constructed to represent one element of a system or the TQM process. After a narrative argument is made for the abstraction of each

[1] Hines, "Molecules of Structure." 2005

system element, the molecule of structure is simulated. The model's response to change in a variety of inputs will demonstrate the behavior of the model under a range of conditions. This step is required to validate that the individual system elements behave as diagrammed. If the molecules of structure cannot simulate and match both the diagram and intuition about real-world behavior, then the element must be reworked or replaced. By implementing this technique, and deriving these ideas from the existing body of literature, a strong narrative argument displaying the behavior of a system under policy or context can be formed.

In the Results section, each of these individual components will be used as a molecule of structure to create a system. In this section, values associated with stocks, flows and tuning variables are selected for purposes of evaluation and demonstration of each structural mechanism. Molecules of structures are typically not linked and only operate with respect to test inputs; this section does not perform analysis on the system as a whole. The goal of this activity is to understand the direction and inflection (the behavior) of each structure and how it reacts to exogenous change over time. The activity is critical to validate the system diagram underlying each molecule of structure; it is necessary before the structures are linked. [2] Any SD model, due to the complexity and interaction of even a small number of loops, will quickly exceed human ability to analyze. Thus, the behavior of individual molecules must be trusted to gain trust in the complete model. Creating "molecules of structure" is no different than unit testing in standard coding practice,

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[2] Verification and Validation are two different activities. Verification is answering the question: did you build the right model? Validation answers the question: did you build the model correctly? In this work the system must be verified to ensure that attribution errors are not committed. Verification in this thesis is primarily ensuring that the model matches the information found in the Literature Review. If implemented for consultation, an iterative process would be engaged with stake holders to improve upon the model. Validation is required to ensure that the code executes correctly and behaves as the physical diagram depicts.

which follows the modeling best practice of defining a system before attempting to change its behavior.

The largest threat to validity in this type of activity is either a specification error or a fundamental attribution error. If the model leaves out a key concept, then a specification error may result. If the model states that A leads to B, when in reality B leads to A, an attribution error may occur. It is also possible that an attribution error may happen if exogenous elements are incorrectly assumed to be internal to the system. A goal of this section is therefore to clearly define the system boundary and all interactions within in order to avoid these classes of errors.

It is the final goal of this section that the reader should be able to translate or map their own experience with Air Force operations onto and understand how their experience might be abstracted within this model. It is highly likely that the experienced operator would want to add loops, modify the implementation, or run additional tests to see if model structures match their own intuitive expectations. If practitioners do attempt such modifications, their insights would iteratively be folded into the model to improve its performance and communicability to other users.

TQM Policy Causal Loop Diagram

The theory behind TQM policy is diagramed in Figure 7 where two reinforcing loops have been constructed based upon TQM theory. In theory, the "Adherence to the TQM Process," or the workforce executing a holistic management and work philosophy, generates Experience with this new way of doing business. As Experience with this new way of doing business increases, new ideas for improving the process are created. Over time, these new ideas are placed into practice and they increase the Efficiency of the system. Higher efficiency equals greater pipeline throughput. The goal of decentralization, according to Creech, grants ownership to workers over their own pipeline processes. The success with increasing efficiency (quality) combined with ownership of process theoretically leads to increases in Morale. Increased Morale should have two direct impacts: people should seek to adhere even more rigidly to TQM and desire to stay in their jobs longer as they derive a large amount of enjoyment from the work. Continual education and leadership commitment also assist with adherence to the TQM process. Longer time on the job leads to a larger experience base in the unit which leads to even greater Efficiency over time. Of critical note are the hash-marks denoting a time delay from "Adherence to TQM process" and "Experience."

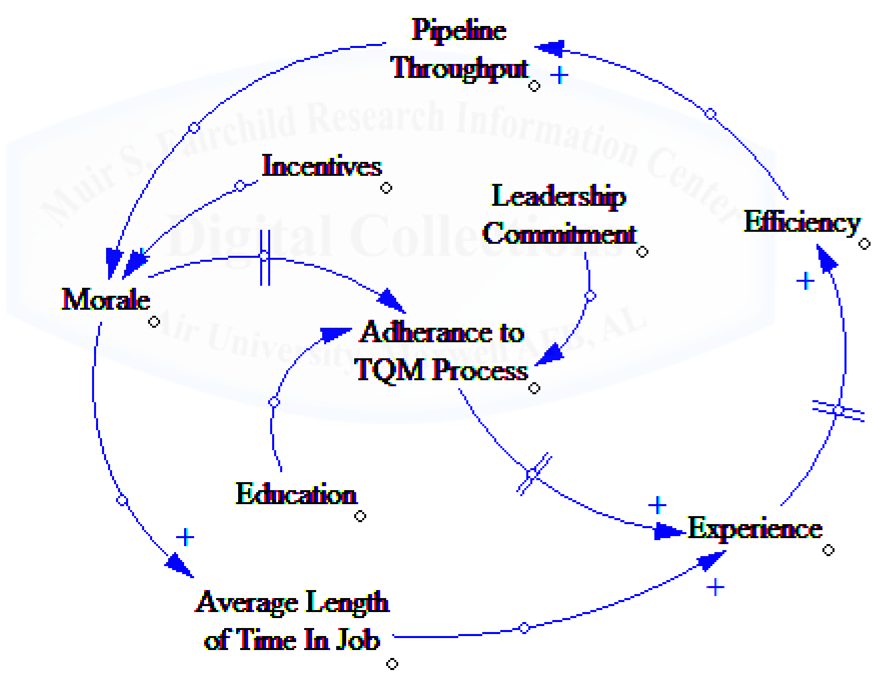

Figure 7: Basic TQM Reinforcing Loops

Source: Author's Original Work

It is very important to note that this diagram indicates that both of these loops are reinforcing in nature. While the positive ideas behind TQM are outlined above, negative operation of the two loops is also possible. Low experience leads to low efficiency, low output, low morale and poor adherence to process. These reinforcing loops can either work for against an organization based on the implementation by leadership. The diagram and TQM theory state that it takes time for experience to grow or decay. The line from average length of time in job has no time delay. If people quit, that experience is instantly lost and will take time to replace.

Molecules of Structure

The core of TQM policy is designed to fight the classic "productivity trap." If a fixed set of resources is available, leaders must allocate these resources between executing a process and improving the process. In a factory, management can either spend money to produce widgets, or spend resources to become more efficient at producing widgets. A problem arises as it is tempting in the short run to shift all resources to production. This temptation may be even greater in the event of a short-term unexpected problem (budget cuts, people leave unexpectedly, machines break down at an unexpected rate) or an unexpected increase in demand. By shifting resources from process improvement to increased production, in the short run more widgets can be produced. However, in the long run, the production process will degrade. This could occur in any number of ways; machinery breaks down due to failure to perform maintenance, root-cause analysis is not performed on failures, or metrics cease to be properly tracked. If this trend continues, over time management will be forced to take even more resources from process improvement and give them to production. This shift of resources is required to cover the shortfall caused by the loss of production due to increased re-work; also known as decreased efficiency or a lower production yield. The eventual state of the system is one that cannot meet demand and has degraded to a low level of efficiency. Leadership has fallen into a classic trap of dealing with the immediate problems at the expense of long-run success. Such an organization cannot remain competitive in the market. Heuristically, it was this class of "productivity trap" that Dr. Morrison was trying to understand in his work and simulations referenced above in Figure 6.

The Productivity Trap

This preference for short-term problem solving versus long-term efficiency clearly emerges in military organizations; sometimes immediate demands of the system must be met. For example, in war it may be impossible to sacrifice resources for process improvement if the enemy is "at the door." A prime example of this behavior occurred in Vietnam where the effectiveness of the Air Force against Russian MiGs was known to be poor, but no one was able to request more training to improve effectiveness. Both the Navy and the Air Force felt there was no time or resources for training. However, the pilots, once in theatre, knew that they had not been sent prepared either in training or with adequate equipment, but had no mechanism to send feedback; they were in a productivity trap in war. Other times, due to the long time delay between investing resources and increased efficiency and/or an uncertain payoff, the decision to stand down and fix a process at a sacrifice to the mission may be impossible to make.

This idea of a productivity trap is transferred to the abstract concept of Air Force flight operations in the causal-loop diagram seen in Figure 8. An organization must fly a fixed number of sorties -- the sortie generation rate -- with a fixed set of resources (people). To meet the operational tempo, this implies a fixed set of resources given an existing level of efficiency under existing practices. If an unexpected event or a decrease in resources occurs, the system must compensate, and resources must be shifted immediately from process improvement initiatives; fixed resources can either be spent producing or improving. If resources are scarce to begin with, the magnitude and speed of the transfer must be greater. Instantly, the sorties flown will increase because resources have been diverted towards launching sorties as opposed to improving the process. The inherent concept of TQM is to fight against this shift, typically through culture, to ensure a high efficiency in the long run. The idea that quality, not cost-cutting, drives down cost is seen here. If the organization attempts to cut cost by removing resources to promote efficiency, over time, quality will degrade, thus negating cost savings. It is likely that anyone who has managed or led an organization knows the pressure of current problems. Moreover, this pressure and its problems are noted in the literature by Caudle and Eisenstat, whose findings will be discussed below in the Results section.[3] [4] Figure 8 presents a basic-production pipeline and shows how it may possess a tendency towards dealing with present problems as opposed to future problems (noted by the hash marks to denote a time delay). However, before the impact of TQM can be analyzed the system in absence of the policy must be constructed.

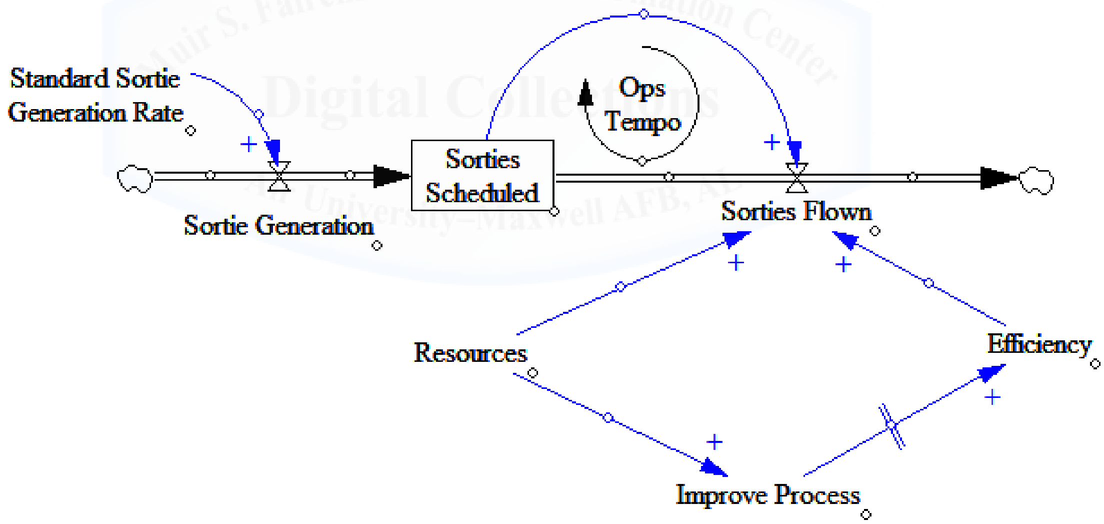

Figure 8: Resources Spent to Execute the Mission

Source: Author's Original Work

Figure 9 expands upon the productivity trap by including additional concepts of the "work harder" and the "work smarter" loops.

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[3] Caudle, "An Analysis of Total Quality Management in Aeronautical Systems Division."
[4] Eisenstat, Spector, and Beer, "Why Change Programs Don't Produce Change."

The “work harder” loop computes the number of sorties that must be flown each week to meet the demand. The diagram shows that as the backlog of sorties scheduled increases, the required sortie rate would increase. Leadership would increase the number of hours each person works to compensate for the increased demand. Thus with more hours worked, more sorties could be attempted. All else being equal, more sorties being attempted will result in more sorties flown. However, over time, long hours will reduce morale.

The “Work Smarter” loop notes that morale has a relationship to efficiency, low morale for a long time leads to lower efficiency (quality). Figure 9 attributes the decrease in efficiency as a result of people attempting to leave the unit faster. In the real world there are many other impacts for overworking people, but all cause impact in the same direction (negative or inverse) and logically result in a less-efficient unit. The SD concept of clustering variables behavior is implemented here. All impacts of overwork and those which are detrimental to morale are encapsulated in this Figure. Importantly, the loop also works in reverse; high morale would lead to high efficiency, which would lead to an increased rate of sorties flown. All else equal over time, a greater rate of sorties being flown would decrease the backlog and again increase morale; this is a reinforcing loop.

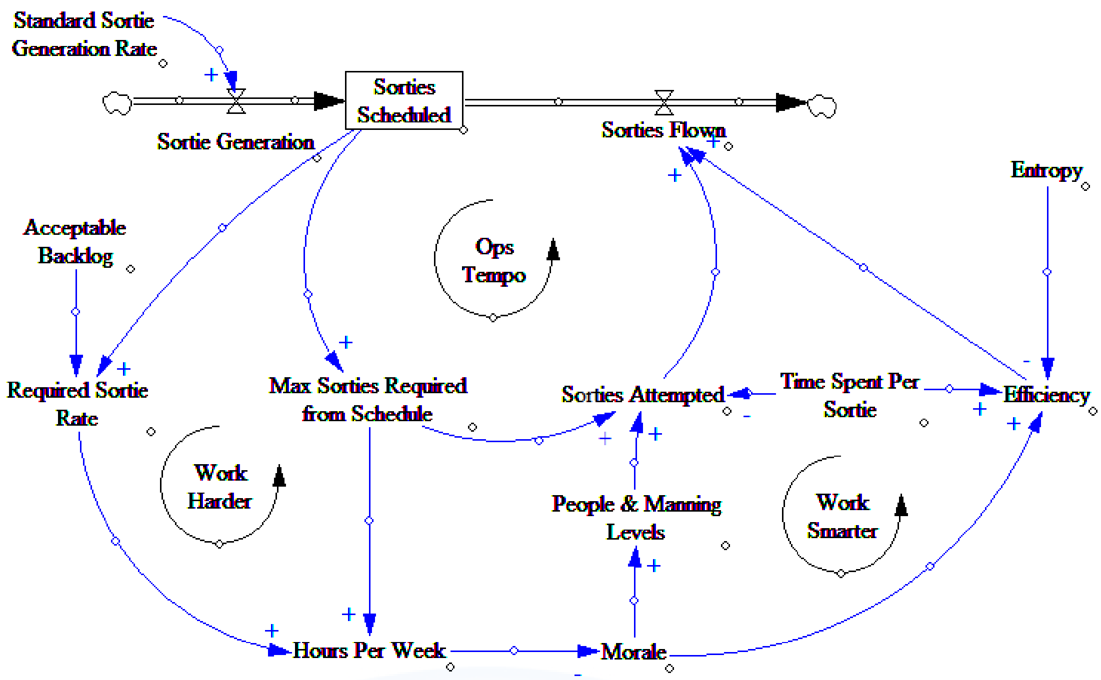

Figure 9: Causal Loop Diagram Depicting Pipeline, People, Morale and Efficiency

Source: Author's Original Work

In summation, this diagram suggests that there are two ways to increase output: either increase the number of hours worked or increase efficiency. Increasing hours worked either requires more people or working people longer. However, efficiency might be free if the right mix of policies are put in place; which is the AF vision for TQM. Unfortunately, Figure 8 and Figure 9 begin to tell a story where leadership would like to work smarter, however context forces the system to work harder. The "stronger loop" is usually the loop with the faster time constants or the loop that is more easily changed. In this situation it is vastly easier to add people or over work people than it is to increase efficiency. Thus, based on these causal loop diagrams, the system has a tendency to tip towards quick fixes with long-term repercussions.

Work Pipeline

Turning now to a consideration of the elements involved in the production pipeline beyond the productivity trap, Figure 10 is very similar to Figure 4: Generic Pipeline with Correction to Changing

Outflow. Drawing from Dr. Hines' work, the difference between the two diagrams is the lack of second stock after sorties flown. In factory production, a buffer of product is kept which forms a backlog of unsold merchandise or widgets. The sales rate of this backlog would then be fed back to either slow or increase the production rate based on external demand. One concept in lean manufacturing is to decrease this backlog by producing goods just as they are needed and thereby making the system more efficient. The model in this diagram is simpler than the archetype developed by Dr. Hines as it is lacking a demand-feedback loop. Typically the demand-feedback loop brings the concept of "customer" into the model. In flight line operations, no customer benefits or purchases the sorties flown, rather they have already occurred. This is not to say that experience or other value is not derived, it simply states that in this model no external actor to the system gets a vote on how many sorties the unit flies in the future; command sets a "sortie generation rate" and the system attempts to meet that rate. While it is likely that leadership might change this number based upon external inputs, for this deductive model this process is outside of scope. In the diagram the variables "red flag exercise" and "reduce workload" represent possible changes to the sortie-generation rate, however, they come exogenously; they are not based on internal performance of the system. The diagram also places the impact of sorties flown outside the model boundary developed in this work, as seen by the flow exiting to a cloud. However, mathematically, the behavior of the remaining model is still the same as in Hines' work on pipeline construction.

In manufacturing, a low efficiency would equate to poor production numbers, or a large number of items being produced that are defective and require re-work. In flight-line operations, this would equate to a large number of aircraft sorties unable to be launched due to broken aircraft, or inefficient operations leading to unfueled planes or personnel not being available at the right place and time (or an infinite number of other issues). As this is an abstract model; these problems are clustered within the variable Efficiency. (This is another example of clustering concepts into a single variable for analysis.)

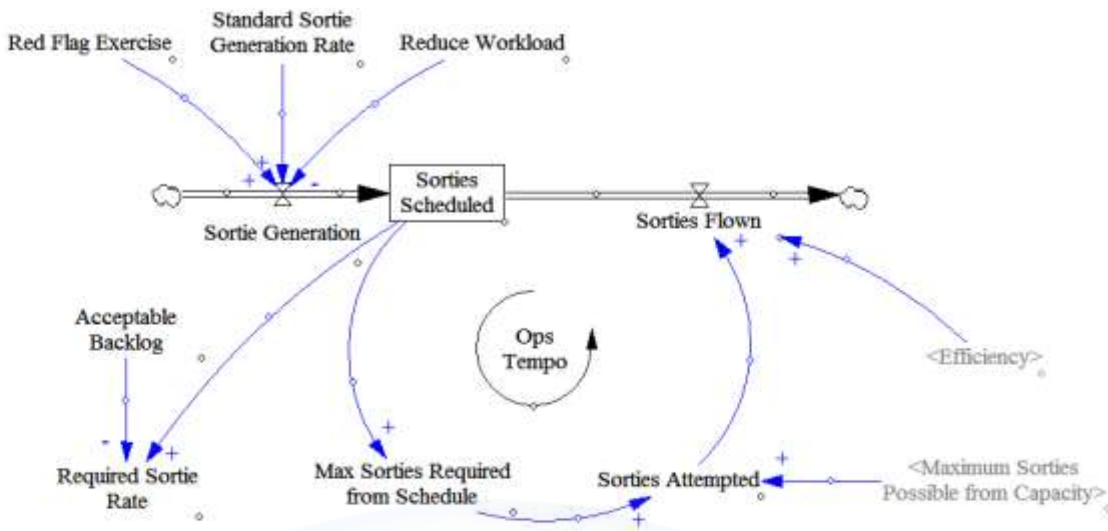

Figure 10: Molecule of Structure, Sortie Pipeline

Source: Author's Original Work

For clarity, in Figure 11 an alternate view of the variables impacting the stock "Sorties Scheduled," originally depicted in Figure 10, is displayed. As shown, sorties flown within any individual time step, a week for the purpose of this analysis is the number of sorties attempted multiplied by the efficiency of the system. The system attempts to complete the sorties in the Sorties Scheduled backlog. Sorties not completed remain in the stock and will be required in subsequent weeks. The number of sorties attempted is modified by the sorties required and the capacity. Efficiency changes with respect to increases in adherence to quality processes or decreases from social entropy. However, for this molecule of structure, Efficiency will be a fixed exogenous constant. This is a reasonable, but not perfect abstraction of reality when comparing the TQM theory.[5]

[5] These three concepts are taken directly from the Literature Review

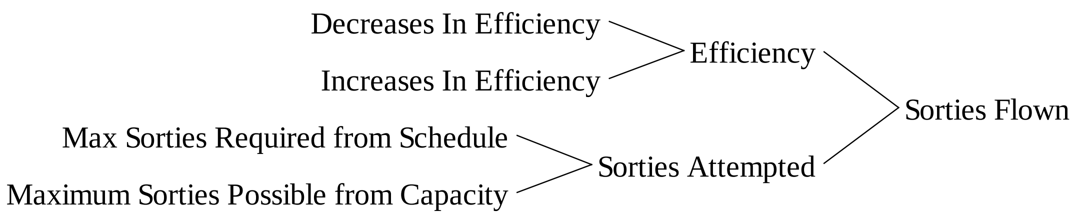

Figure 11: Causal Links to Sorties Flown in Model

Source: Author's Original Work

Figure 12 depicts the results of varying three different exogenous inputs to the sortie pipeline. This begins the process of validating this molecule of structure. To validate the structure of Figure 10, simple conditions are set and the response recorded. Here four basic conditions are tested. The first, shown by the blue line, represents the concept of a "steady state" condition. We will pretend for the purpose of deductive analysis that the system requires 50 sorties a week or 200 sorties a month. Hence, in Figure 12 the blue line is shown at 50 across the diagram. The red line represents a condition where the workload is reduced for two weeks from the normal 50 to 25 sorties per week. Figure 12 shows this dip. The green line represents the idea of a quick increase in workload, labeled "Red Flag Exercise," or a situation where an increase in workload to 150 sorties for a limited duration (1 week) is asked of the system. This is shown as the spike in the green line. The gray line, labeled Insufficient Capacity to Recover, displays the consequence of the same input as the Red Flag Exercise. As this line is an identical input to the third line it cannot be seen as the lines are on top of each other. However, the system response will be different and this difference is seen in Figure 13.

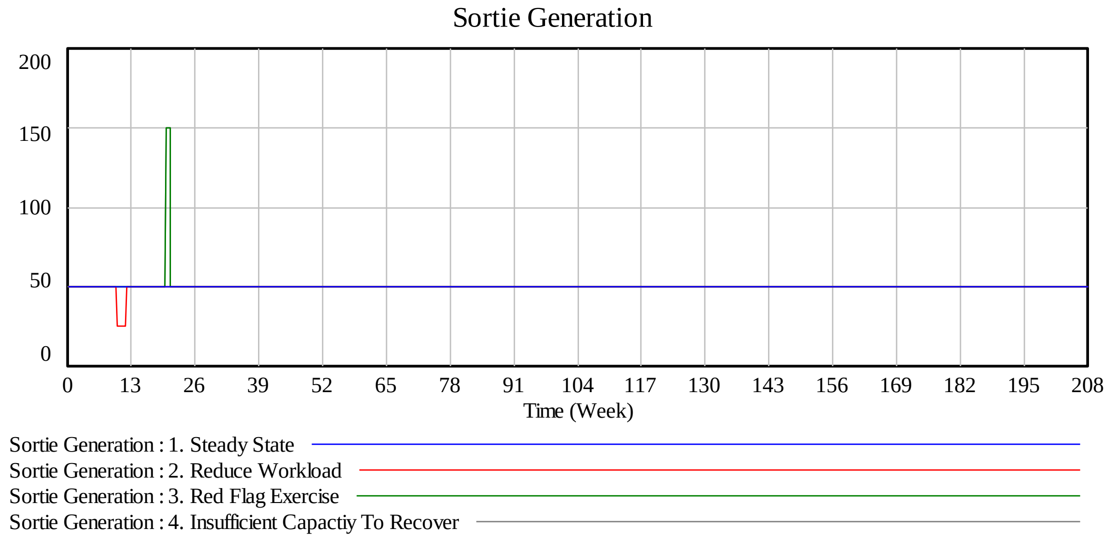

Figure 12: Sortie Generation Rate (Sorties Required Per Week)

Source: Author's Original Work

Developing initial "steady state" conditions is an important technique when constructing a system-dynamics model. Regardless of the loops, reinforcing or balancing, successful system dynamics models should reach a state known as steady-state equilibrium. In equilibrium, the model does not change internally and will only change if acted upon by an outside force.[6] The test of a steady state condition is required to prove that the model can reach equilibrium. Absent of exogenous change, the model must remain unchanged over time; a different result would indicate a malformed model. The steady state condition is the same situation that Creech talked about when he said that systems have inertia or a state to which things will return.[7] More colloquially he stated that the norms of a system "idiot proof" the system, implying that the steady state of the system is found over time as it reaches the point of maximum stability. Establishing a steady state is tantamount to creating

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[6] Technically the steady state equilibrium could be one of sinusoidal activity where the same oscillatory behavior occurs, such as a sine wave, but such a discussion is beyond the scope or utility of this work.

[7] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.

norms of the system. The steady state should mirror the business-as-usual or the historic behavior of the system; it is the narrative story of how the system is expected to function in absence of outside influence. If this work were to be taken to the fourth and final inductive step of system dynamics, then these constants would be tuned to match a real unit's operational tempo.

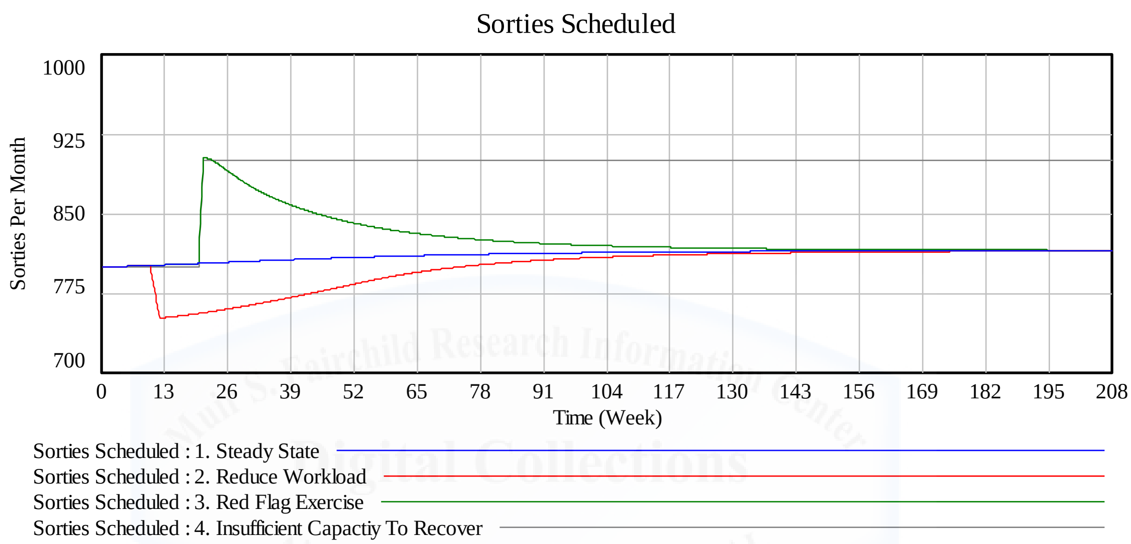

Figure 13: Sortie Schedule, Backlog of Sorties Require to Meet Mission

Source: Author's Original Work

Figure 13 presents the structure's response – Sorties Scheduled - to the inputs of Figure 12: a backlog of 800 sorties and 3 patterns of sortie generation. The blue line, or steady-state input, represents the concept of a backlog of 800 sorties or the projection of four-month's work. The system, as designed, reaches steady state equilibrium of about 800 flights that were never completed.[8] The unit never gets ahead but also never gets behind; it is able to complete exactly 50 flights per week, matching the number being added each week. The effect of a decrease in work demand for two weeks (the 10th and 11th), presented by the red line,

[8] The consequences of this backlog matter and will be discussed in detail later on.

is to initially enable the system to get ahead by 25 flights per week. However, after some time the work backlog returns to the system's steady state. This is the expected response of a system to an exogenous factor: an external deviation occurs and after some time business returns to the normal case. The green line, representing the concept of 100 additional sorties in the 10^{th} week, puts 100 more flights into the backlog. As the system has little capacity for extra work it takes a long time to clear the additional work but eventually the system does return to its steady state.[9]

The grey line shows the result of 100 additional sorties in a week on a system where no more than 50 flights can ever be achieved in a week. While this does not represent reality, it is a good test of the mathematical system response. As the steady state of the system is known to be a backlog of 800 sorties, the addition of 100 more sorties to the backlog should place the steady state of the system at 900; which is exactly what is displayed.[10]

In sum, at this point the system responses seem appropriate, and some verification of the model presented in Figure 10: Molecule of Structure, Sortie Pipeline, and an intuitive understanding of how business should work in the real world has been achieved. The high-level abstract concept of flying sorties has been reduced to a single molecule of structure. The following subsections will follow this same method in creating the remaining molecules of structure.

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[9] The rate at which the structure returns to a steady state does not matter nor does the size of the backlog being 800 sorties. What matters is that these concepts have been abstracted into a model representation. Changing the speed at which the model returns to its steady state is a matter of tuning and changing time constants; this is an activity which should be performed in the third and really the fourth stage of the SD method. As it has been determined that the model is internally balancing and will return to a steady state it has been sufficiently demonstrated that this model abstracts the concept of a pipeline with a "norm".

[10] While not displayed here many more test inputs were run to ensure proper operation of the code.

Efficiency

Previously in the work pipeline, the concept of Efficiency (quality) was assumed to be an exogenous, unchanging constant. In Figure 14, the concept of Efficiency is depicted as a dynamic structure. In Figure 10, a work pipeline is depicted where Efficiency acts like a control gate on the performance of the system. The higher the efficiency, the more sorties could be completed in the same time frame. Comparing to a water hose, efficiency is the nozzle where at 0 no water flows and at 1 the maximum throughput is achieved. Thus, the size of the pipeline might be considered the size of the hose and efficiency the regulation on the flow. In Figure 14, a structure is constructed to represent how Efficiency changes over time.

The math and logic behind this structure are the same as the "process capacity" structure in Figure 6: Dr. Morrison's diagram of resource allocation, pipeline production, experience and capacity. In manufacturing, the concept of rework refers to production which does not meet quality standards and as such must either be discarded or reworked. To cast this in terms of TQM and Air Force operations it has been labeled Efficiency, a concept which includes all activities required to launch a sortie. The diagram shows efficiency always in a tug of war between 0 and 1; a maximum and minimum state, neither of which can ever be achieved. According to the theory of quality management, entropy decreases Efficiency. Cast in the language of flight-line operations, all sources of entropy are currently attributed to changes in personnel. If a greater source of entropy, such as a change in aircraft block or a base realignment and closure (BRAC) were to be analyzed, their impact could also be inserted. However, for this analysis all sources which decrease efficiency, or inject entropy into the system, have exactly the same mode of operation.[11] The system structure will not change if additional sources of entropy are added, only the rate will change; as such this is a good clustering of concepts into variables.

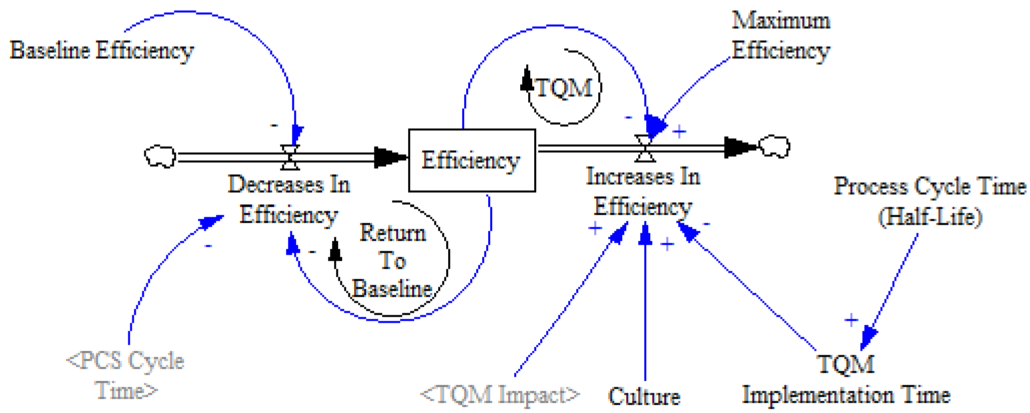

Figure 14: Molecule of Structure, Efficiency
Source: Author's Original Work

Increases in Efficiency are assumed to be achieved through alignment with the TQM suite of policies. The stronger the impact of TQM, the greater the increase will be. However, the diagram notes that culture can play a role (either positive or negative) in adoption, as was noted in the literature.[12] The rate at which TQM can result in Efficiency gains is modulated by the variable Process Cycle Time. In quality management, the Process Cycle Time is a critical component of understanding how often a task must be completed on average and was included in Air Force education on TQM.[13] This "Half-life" variable is the time required that half of the potential gains from the current TQM impact can be achieved. Recall that the logic behind TQM (Figure 7: Basic TQM Reinforcing Loops), was that after front-line workers gain

[11] The SD technique of clustering concepts with the same trend and direction, based on the findings of the literature review, has again been performed.
[12] This is summarized in the Literature Review Summary Section
[13] Kucharczyk, "Inculcating Quality Concepts In the U.S. Air Force: Right Music, Wrong Step," 13.

experience with a process, they will discover and implement new and more efficient ways of doing business.[14] Process Cycle Time captures the time required for the front-line workers to implement these ideas in the process.

Since the implementation of more efficient procedures will require varying amounts of time, the value associated with Process Cycle Time is the "half-life," that is the time required for half of the potential gains from TQM to be achieved. For example, if one believes that after six months, half of the ideas conceived could be implemented, 26 weeks would be an appropriate value for such a variable. The time-based execution of system dynamics uses half-lives rather than discrete time units, as this better captures the concept of average change over time. The first half-life grants half the gain, after two half-lives it is at 75 percent and after three typically ~87.5 percent of the gains have been achieved.

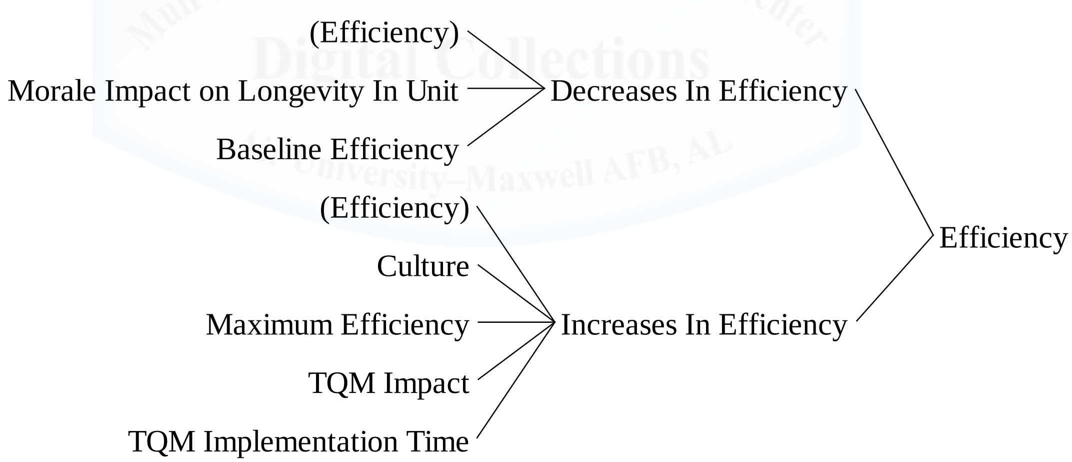

Figure 15: Causal Links to Efficiency in Model

Source: Author's Original Work

Figure 15 is an alternate way to view the causal mechanisms impacting Efficiency. It shows Efficiency is moderated by decreases (a

[14] Beck, "Total Quality…So What Is New?"; Hassan, "Redesigning Organizations: A Case Study of the Air Force 4950th Test Wing Maintenance Complex Total Quality-Based Organizational Redesign."

flow) on one side of the stock and increases on the other side (also a flow). The individual components driving the increases and decreases are also enumerated enabling the tracing of causality.

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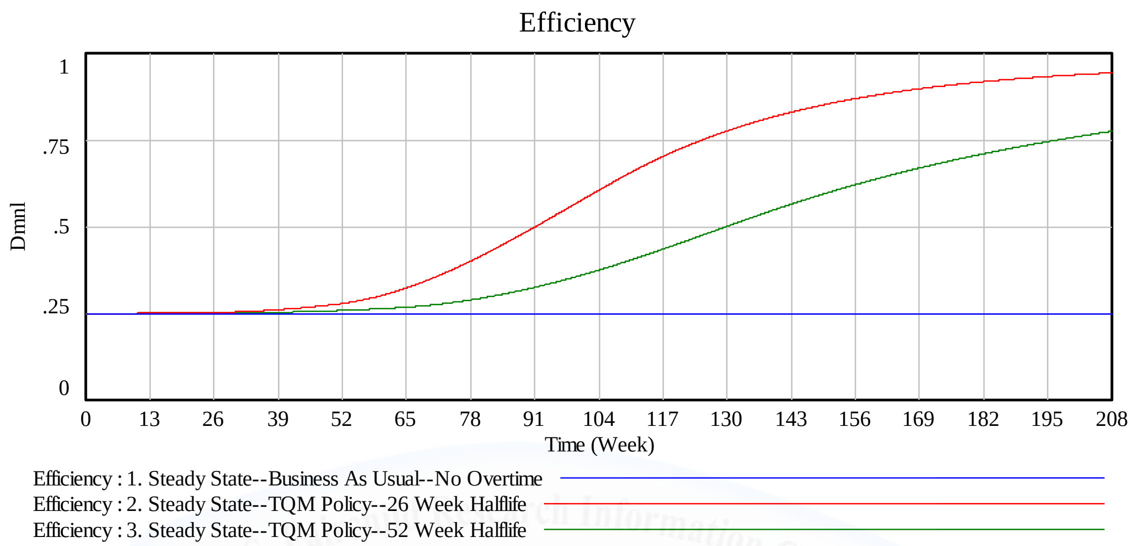

Figure 16: Efficiency Structure Behavior

Source: Author's Original Work

As with the pipeline molecule, the Efficiency structure must be tested. Figure 16 depicts the change in the Efficiency molecule of structure over time when subject to test inputs. The baseline of no TQM policy is represented by the blue line. The blue line again represents the concept of steady-state equilibrium; the value is set at .25 and it does not change. Thus, we can be assured that when analyzing the system under non-TQM operations Efficiency will not change.

To test the response of the Efficiency structure to a potential TQM implementation, a test function was implemented which increased the impact of TQM by one percent each week.[15] Such a variable was hard-coded such that after 100 weeks the unit would be 100 percent

[15] Mathematically this is known as a ramp function of size .01 increasing by .01 for 100 weeks.

compliant with TQM.[16] (This would yield a Process Cycle Time Half-life of 26 weeks.) The red line representing the adaptation to a TQM policy shows the growth in efficiency over a four-year time period subject to this theoretical implementation. The green line represents the impact of a longer half-life: 52 weeks versus the initial 26 weeks. As has been noted, it is easiest for TQM to take hold and enhance operations in organizations where the tasks are easily broken down into repeatable processes. The Literature Review noted that time for implementation can be up to 18 months before positive benefits are detected and from three to five years for full implementation.[17] [18] While this work is deductive in nature it is interesting to see that we have been able to create a model which creates a rise in the efficiency in line with the literature.[19]

One way the model can differentiate between jobs that require more skilled labor, where tasks take longer, or there is greater time in between performing the same task, is through the exogenous variable of Process Cycle Half-life. Through this variable the model can encode the concept of different levels of complexity in tasks and the difficulty with implementing new ideas to improve the process. With a longer half-life, the green line rises more slowly than the red line. As it takes longer for the workforce to implement ideas, even after four years not all of the potential gains have been achieved. As the impact of TQM is not static across time, the difference between existing gains and theoretical gains in Efficiency will also dynamically change. Exactly this behavior is seen in Figure 16 where the “tug-of-war” in Efficiency between entropy and alignment with process is now seen.

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[16] Here again it is worth noting that in the methodology section this type of behavior is undertaken, not because it has a bearing on reality, but to ensure that the model behaves in the predicted fashion and the one depicted in the diagram.
[17] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You.*
[18] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*
[19] This is interesting because this is not a regression model constructing the function.

Another very important behavior in this curve must be observed. The TQM policy was implemented in the 10th week, however, no gains are observed until many weeks have elapsed. This is consistent with the idea that TQM is a policy which takes time to implement. While in the 110th week full TQM implementation has been achieved (all workers are 100% compliant with TQM), it is not for almost another year that the full impact of TQM can be felt. For the green line, full benefit will not be achieved until ~3 years after full adoption. This structure can now translate the idea of a policy, TQM in this case, changing the efficiency of the system. Moreover, the concept of time-lag, as noted by General Creech, has been encoded and demonstrated with this molecule of structure.[20]

Experience and S-Curve

Having constructed the Efficiency structure, it is time to develop the source of TQM impact. In Figure 17, Morrison's work in system dynamics functionality is critical to this analysis. Without the idea to implement learning-curve theory and the concept of the S-curve as an abstraction for alignment with process, this analysis would not be possible. In the literature review, this was the only time based model capable of abstracting soft systems discovered. The additional research of Morrison verifies and validates these structures as an appropriate way to encapsulate the ideas of learning cure theory, a soft-system, into a physical process. If one argues that knowledge is stored within individuals, then only people can have experience. Similarly, Beck argued that experience resides in the mind of the individual.[21] The perfect checklist or routine is worthless without people who know and implement the process. Working with and improving a process takes time to build quality into the system. As was noted in the Literature Review it

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[20] Creech, *The Five Pillars of TQM; How to Make Total Quality Management Work for You*, 27.

[21] Beck, "Total Quality...So What Is New?," 3.

takes on average a year for people to become acclimatized to the culture of TQM and between three and five years for an organization to fully implement a TQM system. To abstract the concept of human learning and then transfer the experience into a higher level of Efficiency (quality) the model implements an S-curve.[22] The S-curve functions as a lookup table to a stock of experience.

Experience with any policy or process is obtained by people when they work with the TQM process; this is input through measurement in the system of Adaption to the TQM principles. In the book *Why TQM Fails and What to Do About It*, the authors note that approximately nine months is the maximal time between when a human performs an activity and when all efficiency with that activity is lost. [23] Thus, a properly tuned deductive model should return to the steady state equilibrium in approximately nine months if a specific experience/policy were to be abruptly stopped.[24]

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[22] One difficulty with translating a "Soft System" or a human system is that it does not exist in reality; it cannot be directly measured. Output of a process can be measured, experience inside a humans brain cannot. However the scientist will note that deductively an S-Curve is likely the most appropriate mode. The S-Curve is the Cumulative Density Function (CDF) of the normal or Gaussian probability density function (PDF). Thus there is an implicit assumption that a normal or average process is in place for this learning function. The slope of the S-curve may change the rate (faster or slower) however; the direction and inflection will not change. This meets the required criteria for deductive reasoning. Arguing against the S-curve as the proper function is inherently arguing against a normal distribution. While it is possible that learning follows a different distribution the author has found no writing to suggest a better approximation, however replacing the S-function with any other look-up function could be implemented if this theory was to be challenged.

[23] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*, 57.

[24] As half-lives are used in this math we would expect between three and five half lives to be the time to return to the steady state initial condition. This would set a half-life value of ~3 months as a potential value to represent entropy.

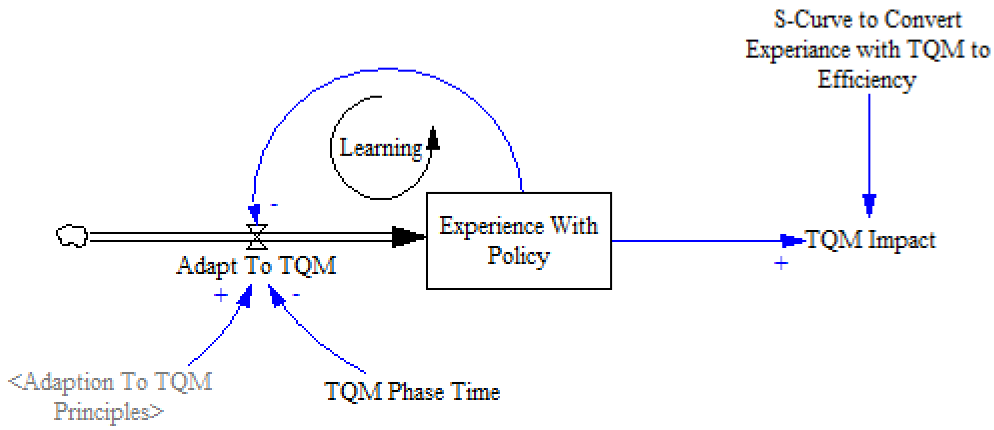

Figure 17: Molecule of Structure, Experience with Policy

Source: Author's Original Work

The variable of TQM Phase Time seen in Figure 17 represents another half-life concept present in TQM theory. Previously in the Efficiency structure we examined the half-life of translating experience into efficiency. Now we examine a similar but different concept, the time delay between implementing a policy and gaining experience with the policy. This half-life is the time between doing a process and gaining 50 percent of the experience associated with performing the function. Some tasks, people may learn quickly, while others might take a long time. For example, how many times does a person need to work on repairing engines for an airplane before they are considered experienced in performing the task? How often does a person need to make a hamburger before they have gained half the experience associated with cooking hamburgers? This value has been defined as the average time for the average person to gain about half the experience with the tasks they perform in the pipeline. Naturally it will vary from task to job to organization. Again, this is different than the Process Cycle Half-life which encoded the time for new ideas to be implemented; this is the time for people to learn the process. This is why in Figure 7: Basic TQM Reinforcing Loops possess hash-marks, unique time delays, in both causal links. Thus, the model encodes both a half-life for learning the process in the “TQM Phase time” of Figure 17, and a different half-life for turning that learning the “TQM impact” into actionable elements which change efficiency previously seen on Figure 14.

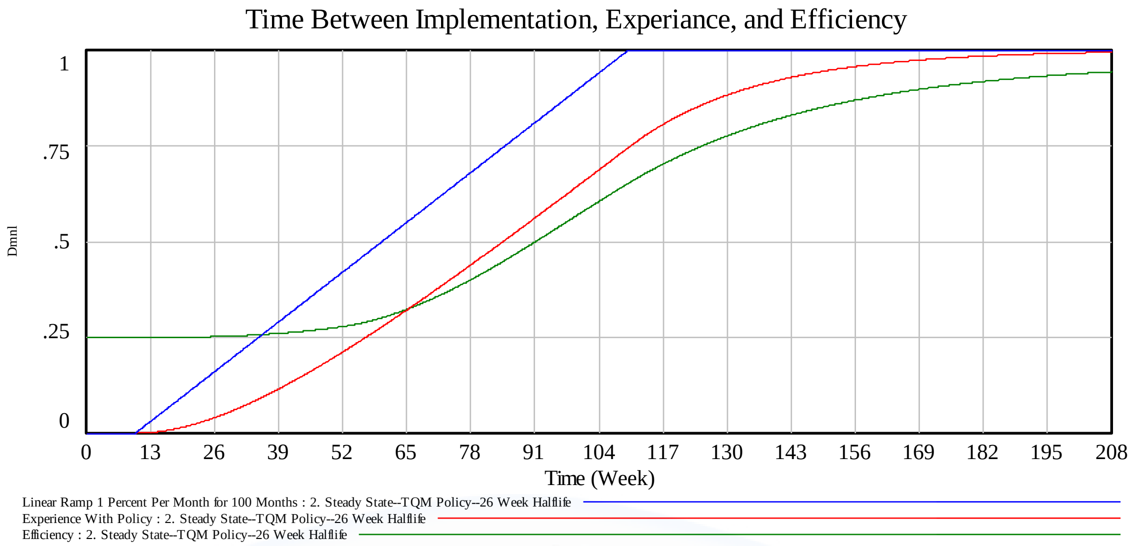

Figure 18: Efficiency and Experience Structure Behaviors Under 26 Week Half-life Assumption

Source: Author’s Original Work

Figure 18 is different from the previous figures in this thesis; it has three different variables overlaid on the same axis. The blue line represents the same test function, a one percent increase per week for 100 weeks, which was used to generate the experience and efficiency previously seen in Figure 16: Efficiency Structure Behavior. The red line represents the response of the structure in Figure 17 to the input of the blue line; the time lag between the blue line and the red line is the impact of the “TQM phase time” or half-life associated with learning the TQM process. The final green line is the same as the red line from Figure 16 representing the efficiency of the system over time. The green line is now seen to be time-delayed beyond the red line, as the process cycle time to turn experience with TQM into processes which improved system efficiency (quality) is not instant. We can now see the two time delays from the two time constants at work. The blue test function starts increasing; this is followed by the red experience line increasing after a time delay. Finally, the green line representing efficiency in the system rises. The time separation captured by such a relationship can now be seen.

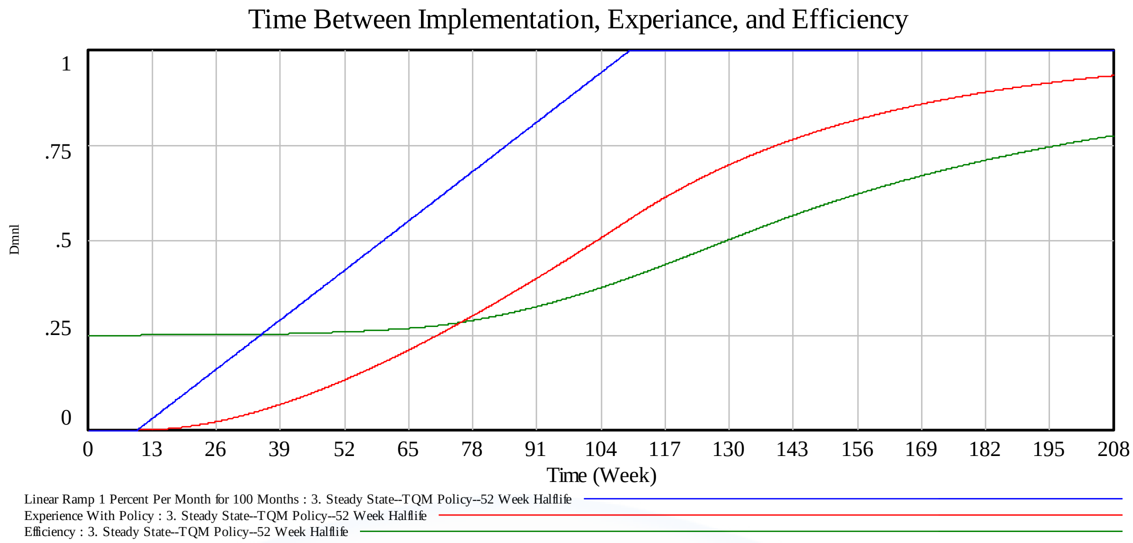

Figure 19: Efficiency and Experience Structure Behaviors under 52-Week Half-life Assumption

Source: Author's Original Work

Figure 19 is included to demonstrate the difference resulting from variation assumed in the half-life or TQM Phase Time variable. In Figure 18, 26 weeks to gain 50% of the experience with a TQM policy was assumed. Now that assumption is changed to 52 weeks or one year. This demonstrates the impact of a more complicated task on adaptation to TQM policy. The more difficult the task, the more skilled the labor needs to be and the longer the implementation time required. Comparing Figure 18 and Figure 19, it is seen that the time delay to reach full experience and full efficiency is longer.[25] Again it is critical to note the change and inflection of the trend lines does not change, only the rate.

[25] In pure math the argument would be made, that all else being equal, a system with a 26 week half-life should achieve most of the gains after 1.5 years where as a system with a 52 week half-life would take three years. However, this linear relationship will breakdown as other causal mechanism may exacerbate learning or forgetting. For purposes of verifying the code, as the test function was set as a 1% ramp per week, the

Workforce

As people ultimately implement any process, experience resides within the individual; humans are the store of experience and knowledge with any process. In discussing Figure 16: Efficiency Structure Behavior, it was noted that people matter to the process as they are the source by which entropy might be injected into the system. Figure 20 is designed to capture the interaction of people inside an organization and the impact of morale on these people.

In Figure 20, the Warrior Spirt loop captures the idea of Morale in the Unit and its impact on longevity of people in the organization. The rate of morale changes, positive or negative, is captured by the flow of Spirit Change. The model notes that people will "suck it up" for some time before morale, changes and there is likely a normal time that people will stay in a given unit. For the deductive purpose of this analysis, the normal permanent-change-of-station (PCS) interval is set to 4 years or 208 weeks. The high turnover rate in the military in conjunction with the difficulty of obtaining experience for new recruits is noted as a difficulty in applying TQM to military operations.[26] The work "Intensity Level" becomes the factor which changes Morale in the Unit. A unit subject to high-intensity operations for a long time will decrease in morale, and a unit with lower intensity might increase in morale. While other factors such as the perception of performance or other carrot and stick activities might also change Morale in a Unit for now these ideas are clustered into the single variable of Intensity Level.

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response of the system seen here indicates that the model is functioning correctly and behaves as is indicated by the diagram.

[26] Beck, "Total Quality...So What Is New?"

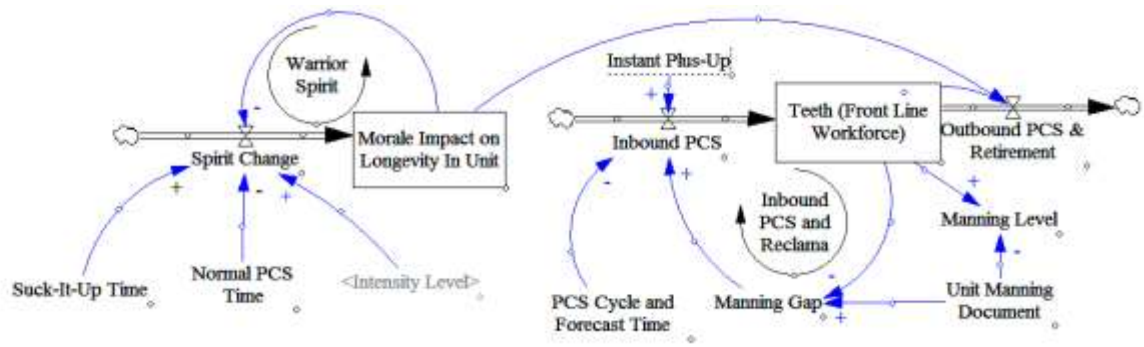

Figure 20: Molecule of Structure, Morale and Impact on Workforce

Source: Author's Original Work

The causal changes possible to the primary structure of "Teeth" or the front line work force in Figure 20 can also be represented in Figure 21. The number of people in an Air Force organization is based on the Unit Manning Document (UDM). The PCS cycle governs the flow of people in and out of an organization. The diagram also notes that people can retire or exit the Air Force through paths other than PCS. In theory, the PCS cycle can update once a year in an attempt to close the manning gap, or the difference between the actual manning and that granted by the UDM. The impact of morale on people's maneuvering to exit or stay in the unit is also included in this molecule of structure.

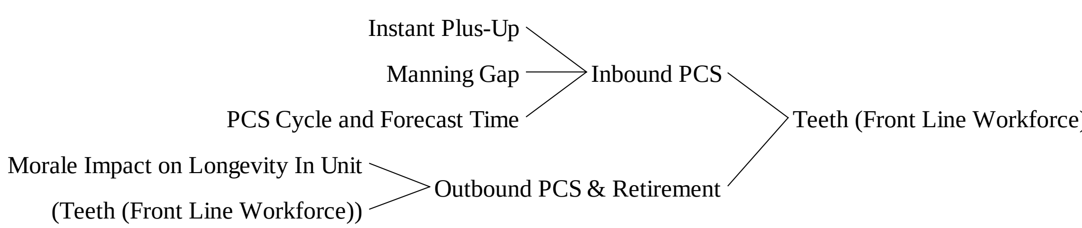

Figure 21: Causal Links to Workforce in Model

Source: Author's Original Work

The molecule of structure represented in Figure 20 is tested and the outputs presented in Figure 22. Per convention, the blue line again represents the steady state where business as usual occurs. For the blue line the average PCS time is ~4 years or 208 weeks. To test the impact of morale under extreme conditions, and show the maximum impact, two test functions were constructed: a high and low backlog of work. In the high condition the backlog of work is increased by a factor of 10 percent and in the low, the backlog is decreased to 10 percent of the steady state. The results in Figure 22 note that these two conditions would either lead people to try and flee the unit in about one year (the shortest time possible due to the PCS cycle) or attempt to remain in the unit up to approximately eight years, nearly impossible for an officer but not unheard of for enlisted -- twice the typical time assumed in a unit. While the Air Force mandates a two-year time on station, it is possible that people can behave in a way where they are actually "on station for less time." They can request deployments, PCAs or even separate from the AF. Actual values need to be representative of reality; and within the context of the Air Force, these may be reasonable bounds for the absolute extreme cases. If this simple behavior matches the intuition of how morale impacts desire to leave or stay in a unit, then the structure represents the impact of work intensity on human behavior correctly.

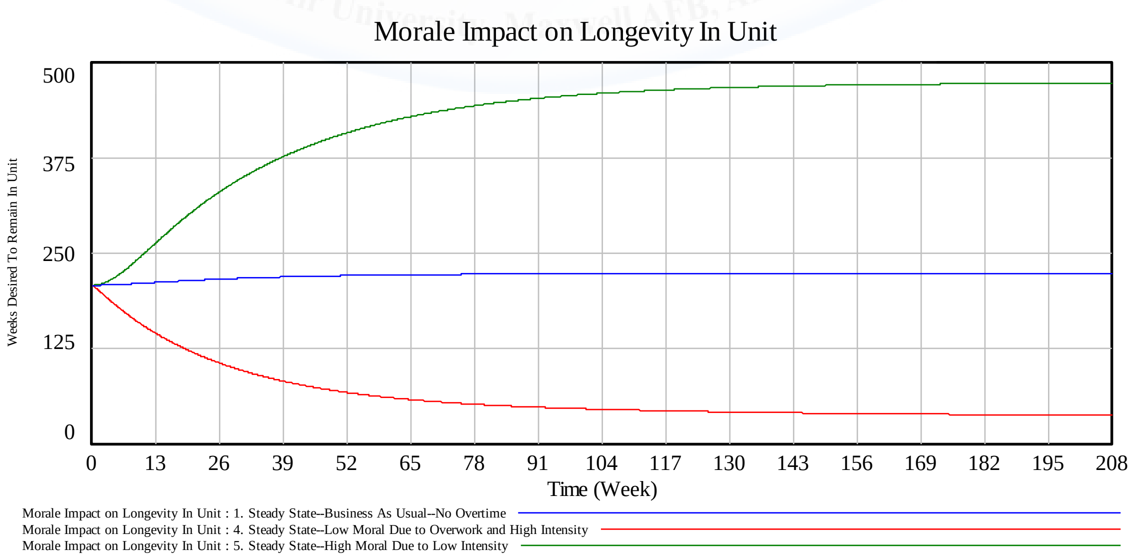

Figure 22: Morale Structure Behavior under Conditions (Extreme Low & High Conditions)

Source: Author's Original Work

Figure 23 is constructed to show the impact of morale on unit manning. High morale can assist in reaching maximum possible manning, and the impact of low morale over time indicates how a unit might shed personnel. Comparing this notion to the previous idea that people entering or leaving a unit are a source of entropy, the expectation is that low morale, through the loss of people, will lead to lower efficiency over time. Moreover, it might also be concluded that low manning would lead to overworking people, if all tasks must be completed and no work can be skipped, thus further reinforcing a low level of morale in the unit.

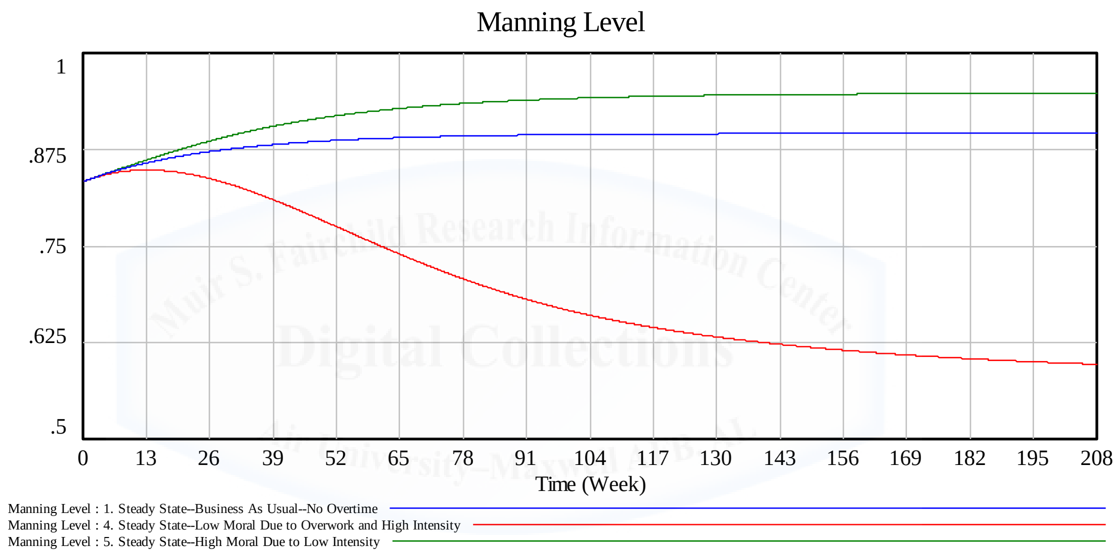

Figure 23: Unit Manning Level after Morale Impact on Workforce

Source: Author's Original Work

The astute observer will also note that this structure and the results in Figure 23 claim that based on the manning system represented, 100% manning is not achieved under normal conditions. From a system standpoint, perfect manning will not be possible in a system that does not allow for the possibility of planning manning over 100%, as unexpected reductions will always lead to losses, and backfill will only be able to replace them at a later date. This may also match the experience of anyone who has served on Active Duty.

Existing System Policy: Overtime

Before examining a more complicated policy such as TQM, the impact of a simple policy of making people work overtime can be examined. Testing a simple policy is useful for two reasons. First, it can assist in validating the performance of the model. For example, all else being equal, having people work 10% overtime should instantly increase output by 10% from a purely mathematical computation. In the real world, this would not be the case, and the complete model in the Results section will find that 10% overtime would not result in a 10% boost. Second, implementing such a concept assists in determining how a real-world activity such as making people work overtime might be abstracted into a system-dynamics model. To this end, Figure 24 performs two functions: a simple and a complicated one. The simple function is computing how many sorties are possible based upon the resource levels available. The complicated function is computing adherence to a policy (such as TQM or the existing baseline). With respect to the simple function, the diagram computes that the number of workers is multiplied by the number of hours each person works per week. This number is divided by the time it takes to complete one sortie. This produces the number of sorties the system can fly per week based on available resources. Thus it encodes resources available into the model in the form of man hours of effort. This brings the initial concept of resources full circle; these resources of man hours can be spent either improving the process or on executing the mission.

With respect to the complicated function, on the left side of the diagram the Required Sortie Rate, as determined in Figure 10: Molecule of Structure, Sortie Pipeline feeds into a variable titled Intensity Level.[27] The underlying concept here is that leadership would watch the

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[27] And this Intensity level is fed into the Workforce Structure previously constructed

performance of the system. If the system falls behind the expected sortie rate, leadership would enact an overtime policy until the backlog of sorties is made. Through this structure, the concept of making employees work overtime can be encoded. In Figure 20: Molecule of Structure, Morale and Impact on Workforce it was determined that working overtime and the relationship to the backlog of effort impacted morale. Thus, it is this Intensity Level that is used to modify the Morale of the Unit. Looking forward, this implies that if leadership works the unit too hard for too long, morale may degrade, decreasing efficiency and leading to fewer sorties being launched despite the increased effort. Eventually, this overrun would lead to a reinforcing loop where the unit could never get ahead of the workload, and morale would continue to erode. Through this abstraction the previously discussed productivity trap is now encoded into this model.

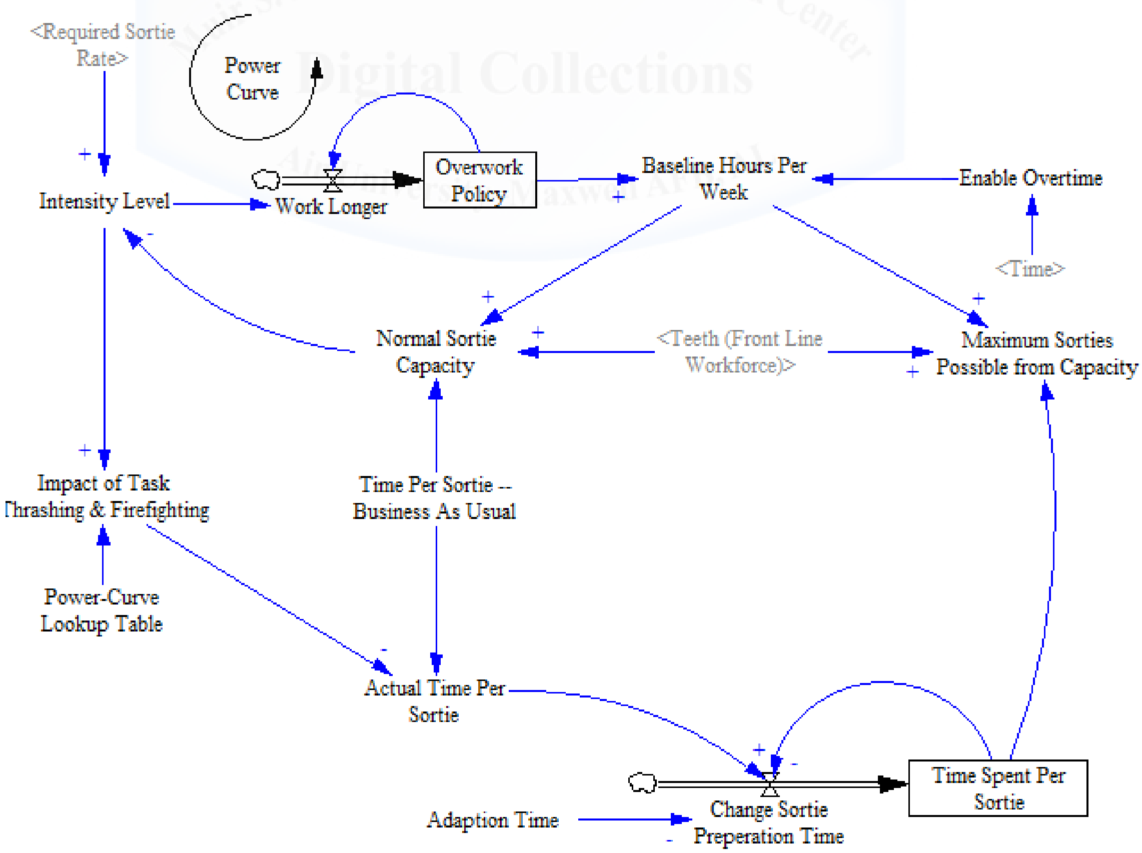

Figure 24: Molecule of Structure, Time Spent Per Sortie and Overtime Policy

Source: Author's Original Work

If the question is how overwork should impact Efficiency in the long run, the answer is found in the Time Spent per Sortie structure of Figure 24. Not only does the Intensity Level lead to low morale over time, but it also impacts how people perform the work. We turn now to the concept of firefighting. When people have only a few tasks to perform, prioritizing is easy. As the number of tasks and the importance of each task changes, however, mismatches between the vision of leadership and frontline workers will appear. Firefighting, the act of switching between tasks without fully completing one task due to external pressure, not only causes inefficiency through task thrashing but also encourages people to cut corners. Given a fixed amount of resources and a fixed number of tasks, the old colloquialism of "good enough for government work" may occur.

For the model, it is assumed that each sortie is nominally allocated 10 hours of effort to complete. However, as the Intensity Level increases, it can be argued that workers will spend less time on each task with the hope of clearing the backlog. Consider the time and effort associated with a policy such as tracking tools. Checking in and out tools for each usage takes more time than leaving tools lying around. In the long run however, if tools are misplaced it can lead to an even greater waste of time or even worse situations related to foreign object damage (FOD). Ideally when a part fails, a root-cause analysis is performed to figure out why the part failed. Over time, this would lead to reducing defects, however, if insufficient time is available to perform such an analysis, workers may simply replace the part without knowing why it failed and move on. This is successful in the short run but will not improve operations in the long run. The result of this type of behavior, diagramed in Figure 24, is seen in the graph of Figure 25 under several test inputs.

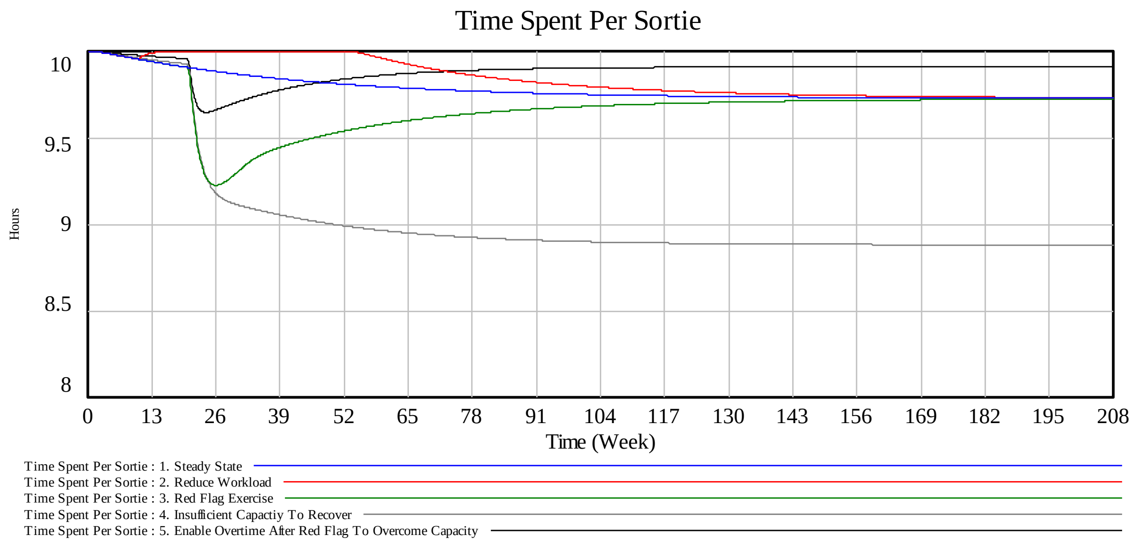

Figure 25: Time per Sortie Behavior under Basic Test Conditions

Source: Author's Original Work

Figure 25 applies the same test conditions used for examining the pipeline's behavior. In the first four test cases, overtime is not allowed in the system; people can only cut corners. However, the fifth test case, overtime as a policy is enabled. The standard, steady state blue line starts at 10 and decreases to ~9.75 where it finds its equilibrium. This is the same as saying we expect the average sortie to take 10 hours of labor but really workers are spending only 9.75 as they are a little bit overworked and need to cut a few small corners to get all the work done inside the allotted time. This puts the system right on the balance point where it can never get ahead but is able to meet the requirement of 50 sorties a week and maintain a standard backlog of 800 sorties per month.

The red line represents the system's response to a decreased workload. The two-week decrease enables workers to spend the full 10 hours and even enables them to get ahead for almost a year. Nonetheless, over time the system tends to its steady state of 9.75. The green line still represents a Red Flag Exercise where additional sorties are required for one week. The response of the work force is to spend less time per sortie to cover the resource gap; one can reasonably conclude what would happen to efficiency[28] if this continued for a longer time period. Still, after a long enough time period, the system is able to recuperate from an extreme week and return to its steady state.

The grey line shows the system performance where no extra capacity to recover exists in the system and no overtime is allowed. This policy is constructed as a test to which the system response permanently forces cutting corners and the establishment of a new equilibrium at less than 9 hours per sortie. This is an abstraction of what a unit might do given a permanent increase in workload and no additional resources. A unit can "surge" for a while but if the change is permanent, people will not continue to work 10 percent overtime forever, and a new norm or stability point will be found. With 100 additional sorties and no allowance for overtime, the model adds 100 sorties to the backlog. This was seen in Figure 13: Sortie Schedule, Backlog of Sorties Require to Meet Mission. The impact of this is that workers, now feeling even more behind schedule, start spending less than nine hours per sortie. Effectively the unit would handle the Red Flag exercise by skipping the normal operational tempo. However, the impact of attempting to do both is that the one hour cut per sortie degrades the performance of the system. Even though the 100 sorties were not accomplished, as long as they are in the backlog, the impact of firefighting and a hit to morale might push a new equilibrium where the maintenance team attempts to fly the average sortie with less than nine hours of work. The impact is that while more sorties are attempted, the lower efficiency of only spending 9 hours on a process that was supposed to take 10 means that fewer sorties execute successfully. Theoretically, the corners cut to save the one hour will result in more problems down the line. The rate of 50

[28] It would go down

sorties per week is maintained, however, it is with a lower efficiency.[29] This might seem counterintuitive as one measure of performance, sorties flows, is technically the same. But, there is a difference; the system is now more brittle and prone to breaking. A threat here is that leadership might not see a difference and simply now set an expectation of 9 hours. A foolish leader might even conclude that the pressure "forced innovation" and believe that the unit was healthier than before. A contrarian view will be seen in Figure 26: Impact of Work Backlog on Morale under Basic Test Conditions, where this higher intensity and lower success rate will impact morale.

The final policy, represented by the black line, is to enable overtime to compensate for an increase in workload. There are two interesting impacts of the overtime policy. First, the system is able to compensate for the increased demand of the Red Flag scenario in a shorter time. For a brief time period leadership forces ~46 hours a week of work, and then this tapers back towards 40 hours a week. The system reaches a new equilibrium for both hours worked per week and hours spent per sortie. However, instead of working 40 hours per week, everyone in the organization now works an average of 42 hours. Instead of 9.5 hours per sortie now ~9.8 hours are spent per sortie. The impact of the additional 2 hours of work per week is shown in Figure 26.

[29] This is a new equilibrium point

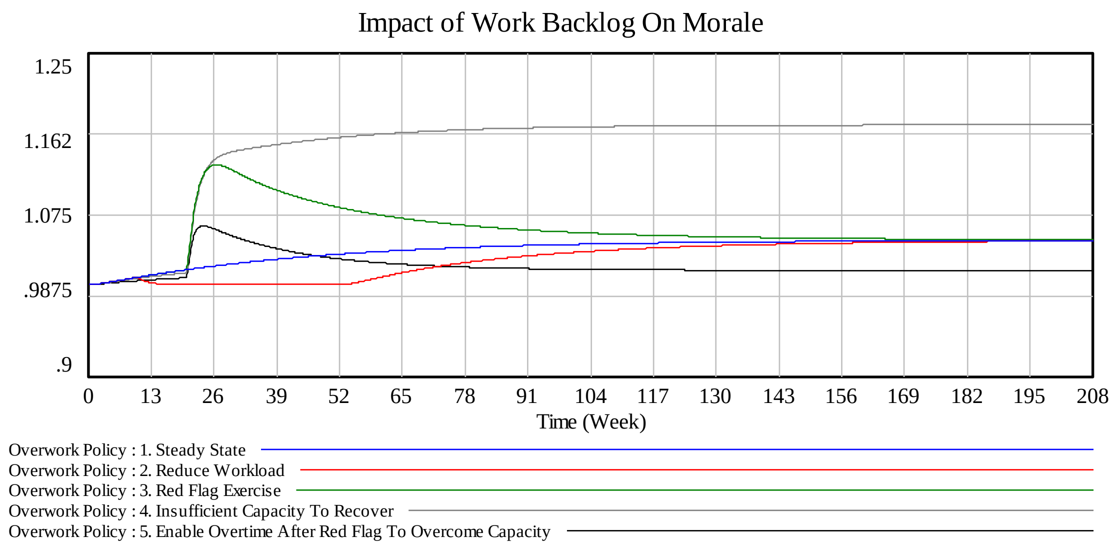

Figure 26: Impact of Work Backlog on Morale under Basic Test Conditions

Source: Author's Original Work

Figure 26 connects the work backlog to morale based on the same five test cases above. As this graph represents impact, lower is better; a high impact hurts morale. As previously noted, the model argues that morale is derived from people's perception of performance and the amount of hours per week they have to work relative to the standard 40 hours. In this model, the metric of performance is keeping the backlog of sorties as low as possible. Changes in backlog and intensity lead to changes in morale across a timeline. In cases where the system can recover, there is an impact, positive or negative, for a short while and then a return to 1 or no change. If the system is not allowed to recover (gray line), a permanent impact to morale occurs.[30] Most interesting is that the authorizing overtime (black line) improves morale once the initial backlog is reduced and hours return from roughly 46 to 42 per week. While deductive, the model demonstrates the capacity to translate the scenario of a unit operating at high performance and ability to clear backlogs while working overtime but simultaneously maintaining morale.

[30] Recall this test case was establish to test the logical system response and is not reflective of reality.

This seems logical, as the choice is to work an extra two hours a week and feel successful or work 40 hours a week and always feel slightly stressed and behind. (If a leader felt that morale and hours worked would follow some other trend or reach some other equilibrium, the time constants can be changed to match their expectation; the model itself does not need to be changed.) Regardless, the concept of being able to work overtime and the idea of people changing their behavior in a process based on work conditions has now been abstracted.

Section Summary

The primary goal of this section was to create and abstract a model of a system representing a repeatable process cast in the language of AF operations. To this end, the policy of TQM was represented as a causal loop diagram consisting of two reinforcing loops. Then six molecules of structure were constructed. Each is presented as a causal loop diagram outlining the abstraction of a system or human behavior. Each molecule of structure was simulated across a range of test inputs. The test inputs validated that each molecule of structure mathematically behaved in the same way that the diagram depicted. Based upon this work, several causal loops were identified which could impact the efficiency of an AF system over time.

Two primary loops of interest can now be identified and we will label them the "TQM Impact Loop" and the "Personnel and Morale Loop." The variable names in bold font are the molecules of structure created in this section. Each of these loops "closes" where the last variable in the list is causally linked back to the first. The variables in bold font represent the stocks; the other variables are the intermediate variables. In SD modeling, time delays occur only between the variables in bold font, all others update at every time increment in the model simulation. Both loops pass through the *Sorties Flown* variable indicating that both impact the number of sorties that the unit is flying (pipeline is producing). Having created these individual structures, in the Results section these molecules are connected and the model simulated as a system.

TQM Impact	Morale Impact on Longevity In Unit
Increases In Efficiency **Efficiency** ***Sorties Flown*** Sorties Scheduled Required Sortie Rate Intensity Level Impact of Task Thrashing & Firefighting Actual Time Per Sortie Change Sortie Preparation Time **Time Spent Per Sortie** Adaption To TQM Principles Adapt To TQM **Experience with Policy**	Outbound PCS & Retirement **Teeth (Front Line Workforce)** Maximum Sorties Possible from Capacity Sorties Attempted ***Sorties Flown*** Sorties Scheduled Required Sortie Rate Intensity Level Work Longer Overwork Policy **Baseline Hours Per Week** Spirit Change

Chapter 4

Results

In the Methodology section, the core elements of a system representing a work pipeline with a repeatable policy and output dependent on efficiency was constructed. The individual components, when connected, as depicted in Figure 7: Basic TQM Reinforcing Loops, created a series of dynamic interactions over time. In this section, the policy of TQM will be represented and then applied to the above system. Simulation of this deductive model will assist in understanding what happens to the system while adopting a new policy. It is expected that three sets of context should emerge: where TQM is impossible, where TQM is easily adopted, and where TQM is possible with assistance from proper leadership and implementation. It is expected that the time constants, associated with the frequency and repeatability of a task discovered in the Methodology section will have a large impact on the success of TQM in a given unit. In reality, success of policy operates on a continuum, not three discrete regions. However, for deductive analysis it is sufficient to find one example of each of the three regions to prove that each are at least possible. It is desirable that the behavior of the model match the findings of the literature review with respect to both success and failure, and time values should roughly represent the time associated with historical TQM findings.

Existing Explanations of AF Failure Modes and TQM

Discussion of culture and culture change started with Deming and was also heavily discussed by Creech. The authors of *Why TQM Fails* write that trust in data is critical; Americans tend not to trust data unless it aligns with their experience.[1] Moreover, there seems to be a cultural hindrance to selecting appropriate measures, selecting either too

[1] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*, 85–89.

many or too few, and being unable to change metrics as needed. On the issue of compensation, it appears that organizations that compensate based on individual performance tend to undermine teamwork. [2] If individuals are rewarded instead of the group as a whole, behavior from unit cohesion may become incentivized; undermining teamwork undermines the cultural change being attempted. One advantage to the Air Force is that its culture promotes teamwork, and individual performance does not change the compensation structure.

In Eisenstat, Spector, and Beer's seminal piece on TQM titled, "Why change programs don't produce change," they note that when one program does not work, senior managers like to try another.[3] They effectively predicted that a failure of TQM in the Air Force would lead to the evolution: TQM to QAF to AFSO21 and onward to the Airmen Powered by Innovation Program. According to Kucharczyk's perception of student behavior at the Air War College, the Air Force implementation of quality evaluation and quality-oriented awards created attitudinal backlash at the Field Grade Officer (FGO) level.[4] The reason for the attitude may have been due to the perception of leadership pushing TQM but then not following through. According to Eisenstat, et al., instituting a rapid progression of quality programs only exacerbates the problem as people build a resistance to ideas that have failed in the past and been obviously rebranded. The authors also noted the difficulty of implementing change programs, as they are designed to cover everyone and everything, so the programs end up covering nobody and nothing particularly well. Change programs are often so general and standardized that they do not speak to the day-to-day realities of particular units. Consider the behavior of the Air Force continually renaming the same

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[2] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*, 114.
[3] Eisenstat, Spector, and Beer, "Why Change Programs Don't Produce Change."
[4] Kucharczyk, "Inculcating Quality Concepts In the U.S. Air Force: Right Music, Wrong Step," 1.

concept but changing it just enough to complicate the process. This is the exact threat to successful TQM implementation that Lt Col Kocon wrote about when he said that the TQM management cannot be a tool to solve problems for which it was not designed.[5] Furthermore, the Air Force will not (is not incentivized to) violate its own "idiot proofing" because there is a reasonable risk that a broken system leaves the country's defenses weakened. A culture of centralized leadership ensures that the system can work, the decisions and insights of one person cannot equal those of a fully functional team. There is risk, however, in the transition from a centralized leader to making a team capable of its own decisions. The period where control weakens before trust is gained in the team's performance may achieve a state of lower readiness for the unit for months to years over an existing centralized architecture.

When Eisenstat, et al. suggested changing the criterion for promotion to grooming those who create the desired culture, they are discussing a theory of competition. This type of thinking is directly in line with Stephen Rosen's argument for how change occurs within the military.[6] Rosen argued that the way to create changes within the DoD was for services to promote junior officers who display the characteristics desired in the change. Unfortunately, it is this exact theory of competition which caused issues for the Air Force. Dr. Binshan Lin noted that one of the realities of AF operations was that some jobs lend themselves to QAF whereas others do not. Kocon feared that an overzealous implementation of TQM, treating TQM like a panacea, could deprive the QAF program of authenticity and cast quality people in the role of priests.[7] Thus, when the Air Force started promoting enlisted troops whose performance reports exuded QAF, it was promoting those who had jobs that were

[5] Kocon, "Quality Air Force and Deming's Fourteen Points," 26.
[6] Stephen Rosen, *Innovation and the Modern Military: Winning the Next War* (Ithaca and London: Cornell University Press, 1991), 253–56.
[7] Kocon, "Quality Air Force and Deming's Fourteen Points," 26.

more easily aligned with TQM, not those that were actually good at it.[8] This violated the exact teamwork structure desired. A pitfall for civilian organizations in quality programs occurs when individuals are monetarily compensated in unit success. In the Air Force, the equivalent undermining of teamwork can result from promoting one person over another, especially if their job arbitrarily aligned with the system. The people who should have been promoted were those who made TQM work in non-“safe” fields.

The Air Force, like the companies studied by Eisenstat, et al., moves managers from one job to another and from one organization to another based on their learning needs. However, the learning needs of managers in manufacturing and the learning needs of an Air Force officer are viewed substantially differently. Air Force leaders put in charge of a TQM or change programs have had careers that certainly groom them to lead Airmen but not prepare them to change culture; rather, they tend to replicate the culture that led to their success. Eisenstat and Beer noted that successful leaders in industry would be sent to units that needed to be changed. Leaders who needed to grow were sent to the model units to understand how they functioned. In the civilian world, companies successful with TQM used “leading edge” units to develop leaders. The Air Force also has similar practices in grooming leaders, however, it is unclear if the growth system functions like the civilian world or even should; this might be a question for future study.

TQM Failures Explained Through Systemic Issues of Time, Experience and Learning

This thesis started with case studies on Air Force successes and failures with TQM in the Literature Review. The model developed in the Methodology section will be implemented and compared to the findings of

[8] Lin, “Air Force Total Quality Management: An Assessment of Its Effectiveness.”

other authors. The results of such simulation and their relationship to existing explanations will generate new insights into the difficulty the Air Force has had with TQM and its program QAF. There exists more than one way to abstract adherence to a process. In this model, the abstraction is based on the amount of time spent on the new policy (TQM) versus the old business-as-usual. The reality of TQM is that on the first day, no improvement is gained. On the second day, it is also likely that no efficiency is gained. It is expected that in the first stages of TQM implementation people are being educated and trained. The introduction of TQM leads to an initial decrease in productivity, all else being equal. As discussed earlier, it is not until the frontline workers are able to deduce possible process improvements, able to test these improvements and then iterate them sufficiently, that they become a new standard process and gains are made. Morrison argues that change from an existing process to a TQM-style process can be modeled by the percentage of time workers spend on the old way of doing business versus the percentage of time spent on the new process. Furthermore, he argues that the mathematical way to represent such adherence is with respect to the percentage of time spent on each process. Thus, adherence to TQM is defined as the percentage of work performed under the old system versus under the new TQM system. Full adoption of TQM is considered to have occurred when all processes are completed under TQM as opposed to the old business practices. As previously noted, this would not be the same time at which full utility of TQM would be delivered. That would occur later, as only after full adoption of TQM could the system reap the full benefit and continue the improvement cycle. Efficiency rises lag TQM implementation based on the time constants discussed in the Methodology section.

This abstraction is especially useful for the deductive model developed in this thesis as the idea of time spent per sortie is already encoded into the simulation. Previously it was assumed that preparation for each sortie under existing process was allocated 10 hours. It was also shown that under stressful conditions the model would capture the idea of cutting corners if not enough time was available to meet all the requirements. In applying the TQM process it will be assumed that initially each sortie will take 20 hours of preparation -- a doubling of the man hours required. The additional 10 hours is based on what TQM requires derived from the literature review. TQM needs:

1. People to spend many hours in continual training
2. People to spend time continually developing and revising metrics
3. Time to track and record metrics
4. Time to develop process improvements
5. Time testing and implementing improvements
6. Time to work up and across the chain of command and resolve issues that cannot be solved internally. (e.g., supply problems or defects)

The model abstracts the man hours required for the above six activities into the additional 10 hours. It is worth recalling that because TQM stresses decentralization or pressing authority for such activities to the lowest possible level, the individuals performing the process are also the ones who must improve it. While in reality the time required for such activities may be more or less than double, this is a good approximation for deductive understanding.

The consequences of such an assumption mean resources required should instantly double. Thus, a key role for leadership under TQM is to grant support for and monitor the adoption of TQM. (In contrast with this, the literature notes that military organizations were often unable to grant delays when implementing TQM. TQM theory states that leadership must work with the front line work force to determine where and when to target process improvement. It is highly unlikely that obtaining a reduction of 50% work or an instant double in manpower will ever be fully viable; as such implementations typically go after the low hanging fruit first as directed by leadership. For example, when Creech first attempted a policy change in TAC in 1978-79 he began with the simple concept of decentralization. Instead of all maintenance handling all airplanes in a squadron, individual maintenance crews were assigned to individual aircraft. Famously, he reasoned that while people do not often maintain or wash rental cars they do take good care of their own cars. In the first year, efficiency in the sortie generation rate in TAC increased by 11%. In TQM, the early fixes are usually visible to and implementable by leadership. It is the later improvements that only the frontline workforce can see. Thus, during the early days when leadership proposes initial fixes, metrics, and process improvement projects, it is incumbent on leadership to make the frontline workforce own these changes. The ownership of improvement is necessary to empower people at the lower levels to create the next iteration of improvements. It is this behavior of beginning and transferring process improvement the model wishes to capture.

Here Figure 27 adds a new structure to Figure 24 of the methodology section, the implementation of a TQM policy. This structure enables the model to switch from the business-as-usual case to implementing TQM. In the Methodology section Figure 24 laid the time spent per sortie given, an existing set of policies, an organizational norm, and a policy of overtime.

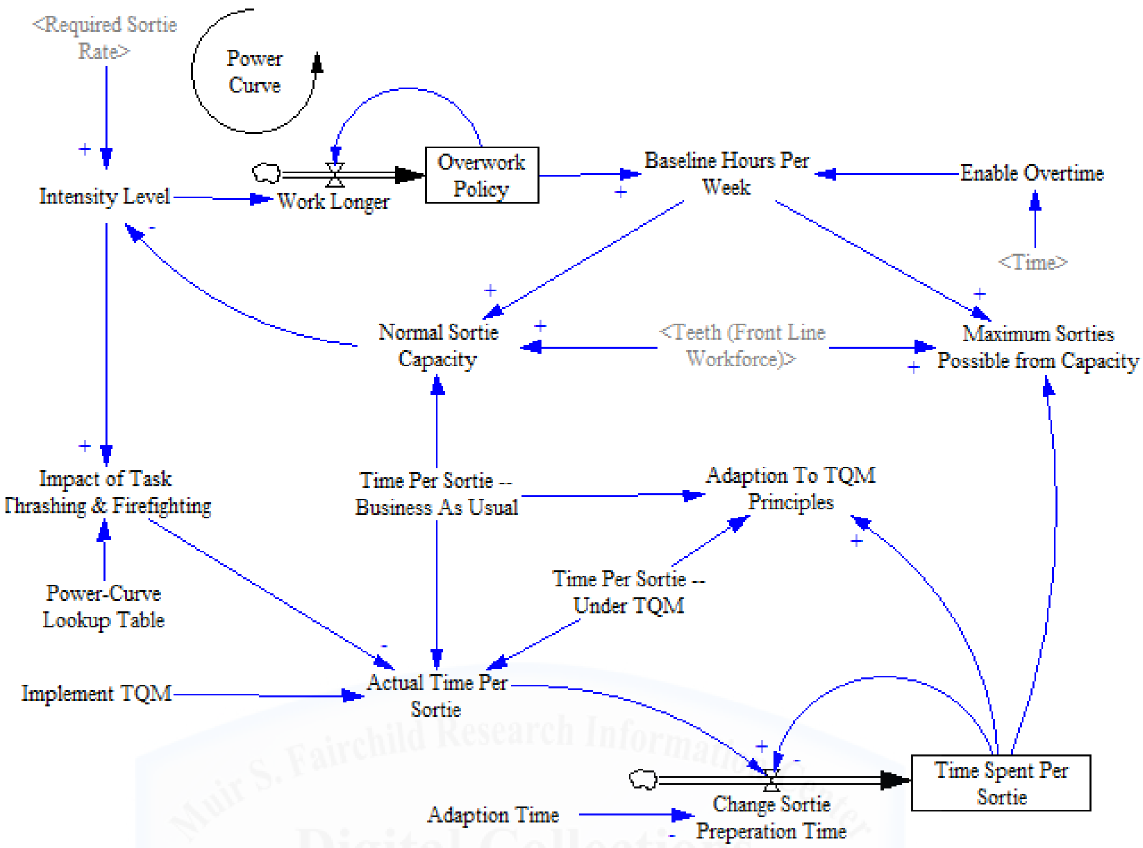

Figure 27: Molecule of Structure, Time Spent Per Sortie, Overtime Policy and Adding TQM Policy

Source: Author's Original Work

Figure 24: Molecule of Structure, Time Spent Per Sortie and Overtime Policy brought together the idea of human behavior in the system subject to context. Figure 27 fully completes all causal loops seen in Figure 17: Molecule of Structure, Experience with Policy by creating a measure of "Adaptation to TQM Principles." This is the model's way of abstracting the idea of changing the context and being able to track the change in resources. The stock of time spent per sortie when compared with the variable with time per sortie—under TQM will measure the adaptation to TQM principles as proscribed by Morrison.

Changes in Efficiency

Figure 28 displays the results of implementing a TQM policy based on the implementation depicted in Figure 27. Previously the time spent per sortie was set at 10 hours. To encode the concept of implanting a TQM policy, the "time spent per sortie" is doubled to 20 hours. If Efficiency starts at .25 it must double to .5 in order to justify the doubling in time per sortie, otherwise the increase in Efficiency is not a net positive against the policy.

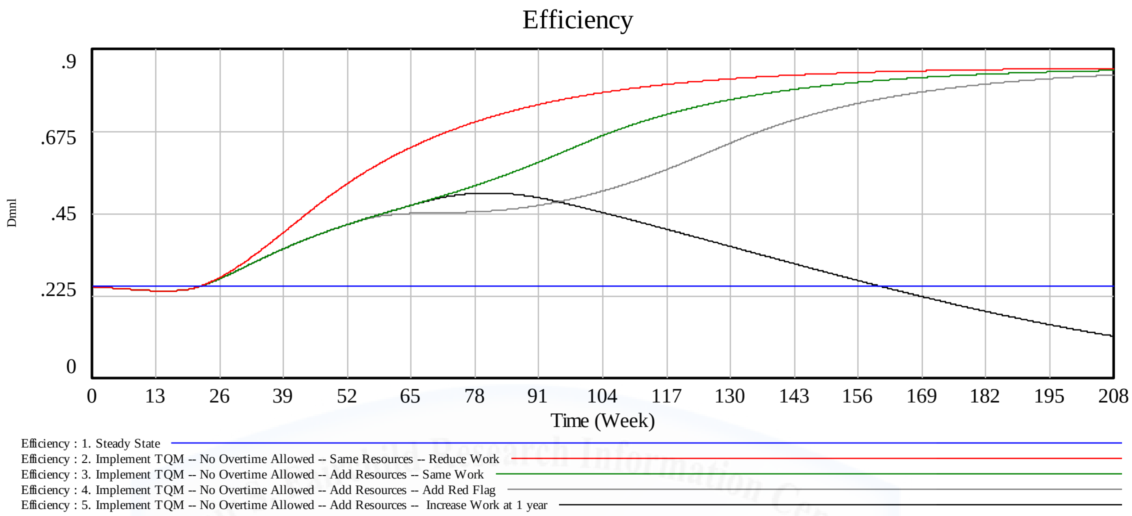

Figure 28: Impact of TQM Policy on System Efficiency

Source: Author's Original Work

Figure 28 displays the steady state of the system and four test conditions run through the model. The steady state (business-as-usual case), which represents the system with no TQM policy in place, appears as the blue line. The next four policies involve implementing TQM in week 10 but varying other conditions to analyze the system response:

2. Implement TQM –reduce the work load by 50% for 26 weeks – red line
3. Implement TQM –, keep the same workload but put manning at 100% --green line
4. Implement TQM – with a Red Flag exercise after one year – gray line
5. Implement TQM –keep the same workload, manning at 100%, but double the work load after one year – black line

A reduction in work for up to six months (red line), is an ideal TQM implementation. This case represents leadership supporting the requirements of long training times and a reduction in productivity for a full process-cycle time (26 weeks). Under this condition, all the time required to train low-level employees as well as the time required for employees to experiment on the job with new ideas is granted.[9] As the model was initially assumed to have a Process Cycle Time of six months, the six-month reduction is a full time period.[10] The result of this policy of work reduction for a six-month process-cycle time is that TQM succeeds and Efficiency rises to its maximum level under TQM in approximately three years. Here the model demonstrates what successful TQM implementation looks like from a modeling standpoint: a rise in Efficiency over a multi-year time frame. After three years this unit would truly be capable of nearly double the work given the same manning level.

If no reduction in work is possible, the green line represents an alternative policy where unit manning is brought to 100 percent and kept at 100 percent (instantly replacing any losses). This grants additional resources in the form of man-hours to the system. If leadership cannot support TQM introduction by reducing work requirements, it may be they can give more workers. As previously observed, low morale may lead to lower manning levels. To avoid this, with TQM introduction, leadership must take interest in this unit and aggressively fix the manning issues, not trusting the system to regulate acceptable manning levels. With the process-cycle time remaining at six months, and under this policy of increased manning, efficiency is able to rise, not as quickly as with the acceptance of reduced production (the red line), but still successfully over the course of three to four years.

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[9] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*, 9.

[10] If the process cycle time was a year, according to theory one would need to grant this 50% reduction for a full year, however, the results would not be identical across time as will be seen later.

The grey line inputs the same manpower increase as the green line, however, one year (or two process-cycle times) after implementing TQM the unit is called upon to support a Red Flag exercise. For demonstrative purpose this additional work was intentionally levied at the same time that the Efficiency approached the .5 mark. What we observe in Figure 28 is that the idea of TQM has almost, but not quite, “caught” in the system, thus it is not ready for the sudden increase in workload. The shock to the system undercuts the gains made over the previous year. Forced to complete a Red Flag exercise, the workforce chooses to abandon the TQM process and instead cut corners to meet the increased work demand. For example, workers may stop tracking metrics or may stop meetings for implementing new processes. They may also halt implementation of new ideas. As the efficiency has risen from .25 to .45 the unit is able to meet the Red Flag requirements but is unable to maintain commitment to the TQM process. This abstraction is represented below in Figure 29: Impact of TQM Policy on System Behavior, Time Spent Per Sortie.

Unfortunately, while it is possible that leadership and team would be praised for their efforts and success in meeting the demands of the Red Flag exercise, there is a ripple effect: after the exercise, Efficiency for the grey line grows much more slowly than the green line for over a year. This is a second-order consequence of too quickly demanding too much from a TQM process. While the Red Flag exercise appeared to have been successful, it created a major setback for TQM implementation. If this same exercise were required after two years (four process cycles) the same setback would not have occurred. TQM would have been fully entrenched and the team would possess such high efficiency that the increased work load would be borne by the system without cutting corners. This is a difficult reality to measure at any instant in time, as in the real world the concept of Efficiency, outside of a pure maintenance or manufacturing unit, is hard to quantify.

The final scenario is represented by a black line. In these circumstances, management for an entire year grants full manning to the unit and the Efficiency rises, even beyond .5. However, management believes that TQM is a process which is supposed to increase throughput and wants to cash in on the investment. So after a year 100 percent manning is dropped. Moreover, leadership increases the expected sortie rate of the unit after one year. The instant result is not terrible. The efficiency continues to rise for several weeks, which would give the initial impression that TQM had caught and that leadership might go on to the next problem. However, after a little more time, Efficiency starts to decrease and the decline never stops. The black line represents a condition under which TQM would be considered a failure or perceived to have not delivered on its promise. According to the authors of *Why TQM Fails* this would be the model's representation of failure in alignment.[11] The reason for this initial success followed by failure is complicated and will be unpacked below.

Figure 29 depicts the number of hours spent per sortie. The blue steady state equilibrium in the previous two graphs is present and fixed at 10 hours per sortie. The impact of both increasing resources and decreasing requirements can now be seen on the various lines. Most importantly the goal of abstracting human behavior inside the system has been achieved. Over the course of several weeks all the lines shift from 10 hours to 20 hours per sortie. This line abstracts the action of leadership ordering the implementation of TQM activities. The unit responds as such and spends time on quality-control activities. Over time the activities start to bear fruit and the unit is able to spend more time on quality activities and efficiency rises and rework decreases. In the red line or "easy case," the unit is nearly always able to spend the full 20 hours per sortie, and TQM succeeds as seen previously on the plot of

[11] Cite Why TQM fails and what to do

efficiency. After hitting 20 hours, the green line quickly regresses to ~14 hours per sortie before returning eventually to 20 hours per sortie. This is the representation of mission failure. As such, workers start cutting corners and are not able to commit fully to the TQM process while also maintaining a reasonable level of performance. In this situation some TQM implementation over time leads to gains. This leads to higher efficiency and the ability to devote more time to TQM, eventually leading to the full implementation after ~100 weeks.

The grey line shows the impact of the Red Flag exercise, where a large pulse of work strains the system after one year. Additional corner-cutting takes place within the unit, and the shock to the system lasts far beyond the two-week increase in work, during Red Flag. The difference between the green line and the red line can be thought of as the gains not made due to the exercise before the unit was ready to increase work. Had the Red Flag exercise occurred on or after week 100, no corner-cutting would be seen as the unit would have been able to handle the increased demand.

Finally, the black line shows how the unit is broken and the time lag associated with breaking. For a full 26 weeks after doubling the required throughput the unit continues to maintain some of the TQM implementation; the line remains above 10 hours. Even after the line crosses the 10-hour mark, the efficiency remains above .25 for almost a year, as seen on Figure 28. This time lag would likely place the blame for failure on the person in charge one and a half years after the decision which broke the unit took place. In reality the time between a decision which breaks TQM introduction and its obvious failure could be even longer. The impact of time between a decision and when that decision impacts the unit may be hard to connect. This is a systemic issue, not one of leadership, even the best leader would be unable to know the true second-order consequences (positive or negative) of a decision under a policy such as TQM for a long time.

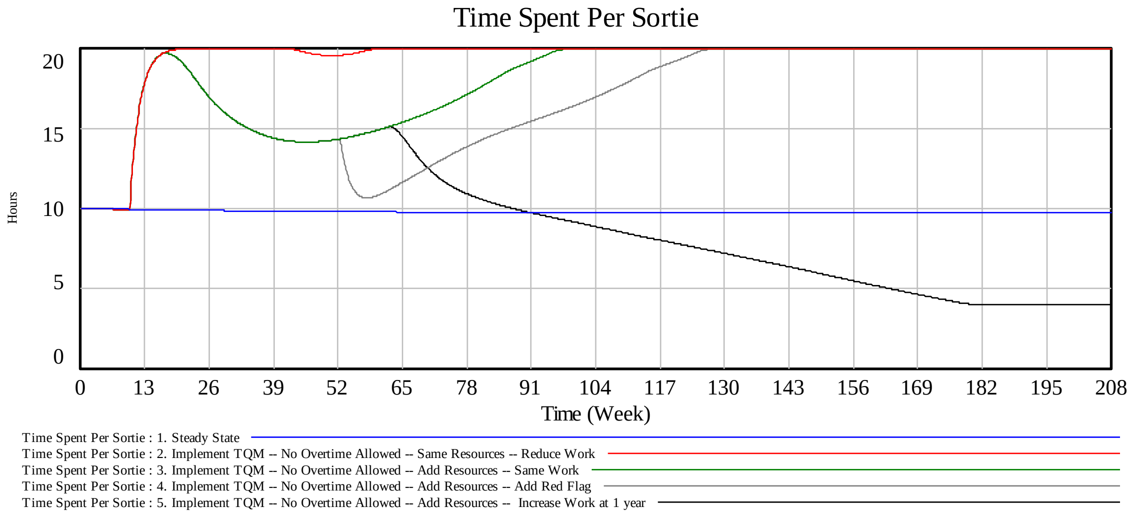

Figure 29: Impact of TQM Policy on System Behavior, Time Spent Per Sortie

Source: Author's Original Work

Figure 30 displays the number of sorties in the unit's backlog; each simulation starts with the steady state equilibrium of ~800 sorties in the backlog. Again, the red line shows the unrealistically easy case where leadership allows a 50 percent sortie rate for 26 weeks. The unit is able to quickly implement TQM and gain valuable experience as it is consistently able to devote the full 20 hours to each sortie. Unit members are implementing the new process and gaining experience as quickly as possible.[12] Thus the backlog of 800 sorties quickly decreases. The impact of the slower gain in efficiency for the green line on Figure 28 can now be seen in the rate at which the backlog is cleared. Initially leadership enforces the TQM policy and 20 hours are spent per sortie. However, quickly a backlog of work appears as there are insufficient resources (manpower) to spend 20 hours on each sortie. The green line on Figure 30 increases to a backlog of ~1000 sorties from the initial 800. Even with the instant increase in work force, it may appear that the situation is getting worse from this single metric, which might lead to leadership

[12] The little dip in week 52 indicates this is very close to the minimum sacrifice in performance required to implement the policy as quickly as possible.

inappropriately tinkering with the program prematurely. However, the simulation indicates that, while there may be growing pains, some of the TQM policies are implemented and the backlog does not become unwieldly. Educated leadership tracking these metrics would probably rationalize (correctly) that this is a growing pain but not sufficient to break the unit and would continue with implementation. While the backlog leads to more “firefighting” behavior, experience with the process is still gained, though at a slower rate. This leads to a successful, but slightly slower, adoption of TQM. Conditions for success are still sufficient, but implementation requires nearly a year more than under the ideal adoption circumstances.

The addition of a Red Flag exercise in the 52nd week, seen in the grey line, shows how a too-early demand for additional capacity derails TQM adoption. The need to meet additional requirements before the system is able to bear the extra work causes the work force to regress by cutting corners and not taking the proper time on each task required to maintain the TQM implementation. This single event is enough to take ~9 months to recover. While in reality this may seem unrealistic, the value of this deductive simulation is to show setbacks can impact the adoption of TQM and to indicate the fragility associated with attempts to change a system given the inherent desire to regress to the original steady state. TQM once in place as a policy is very resilient to exogenous shocks. However, during the shift from one equilibrium state (business as usual) to another e (TQM) the system is very volatile and the tendency (organizational inertia) is to regress to business as usual; the “idiot proofing” at work.

The final black line shows the consequences of increasing the workload before the TQM process has taken hold: all gains are lost and the overhead burden of TQM and its processes result in a lower Efficiency than when the process began. At some point TQM would likely be abandoned given that it drives Efficiency below the business-as-usual case and the backlog “blows up.” Detecting that TQM is failing and making attempts to fix it might, however, require several years. Even after the process is “broken” or becomes unstable the system is able to maintain flight operations for over a year. Even worse, in abandonment it is likely that the reasons for failure might never be understood.

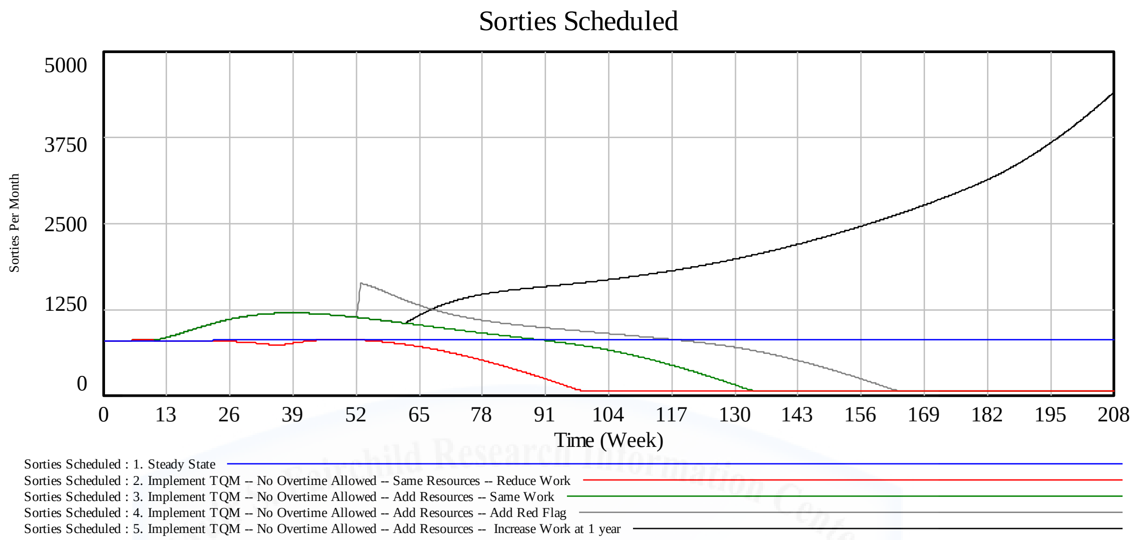

Figure 30: Impact of TQM Policy on System Behavior, Sortie Backlog

Source: Author’s Original Work

Effects of Varying Modeling Assumptions

The above model is based on available TQM literature. While ideas about workloads, efficiency, morale and commitment of leadership are present in the literature the idea of time is often only implicit. After this systemic analysis several key time variables and their impact have become apparent. However, the discussion of TQM and its theory of implementation clearly centers on time and an iterative process.

1. The time required for a person to gain competency with a task
2. The time required for a unit to generate new ideas
3. The time required for new ideas to be implemented and evaluated

Each of these times will be different in different units as a function the nature of the work the unit performs and impact of the rise of efficiency on their work. It is noted by many authors that the time for TQM implementation is usually longer as the skill required for labor increases. There is, however, no literature which breaks out these specific time values.

The model was executed with the half-life or time constants set at 26 weeks. It is important to note that, as there will be many ideas and programs within a TQM implementation. As such, these time-constants function as the average for all ideas moving through the TQM cycle. In the Methodology it was argued that time constants should be implemented as half-lives or the average time for 50 percent of something to occur. The model does *not* encode TQM as a linear process where it takes 26 weeks for people to gain 50 percent competency, then 26 weeks for people to generate 50 percent of new ideas and then 26 weeks for people to implement and evaluate 50 percent of those ideas. Instead, 26 weeks is the average time for ideas to flow and mature throughout the system.[13]

Impact of Extending Half-Life on Efficiency

To illustrate this point Figure 31 illustrates the consequences for efficiency of changing the assumption of 26-week half-lives to 52-week half-lives. If the Process Cycle Time was 26 weeks to gain 50 percent of the experience with a task it is now 52 weeks, the same is true for

[13] In system dynamics this works out to the mathematical equivalent of half the time to close the gap. E.g. a variable X is at 5, the current goal is Y = 10. If the half-life is 2 weeks then it will take 2 weeks to move X from 5 to 7.5; half way to 10. Naturally, as this is a dynamic system the values of X and Y might also be changing along the way.

generating and implementing ideas.

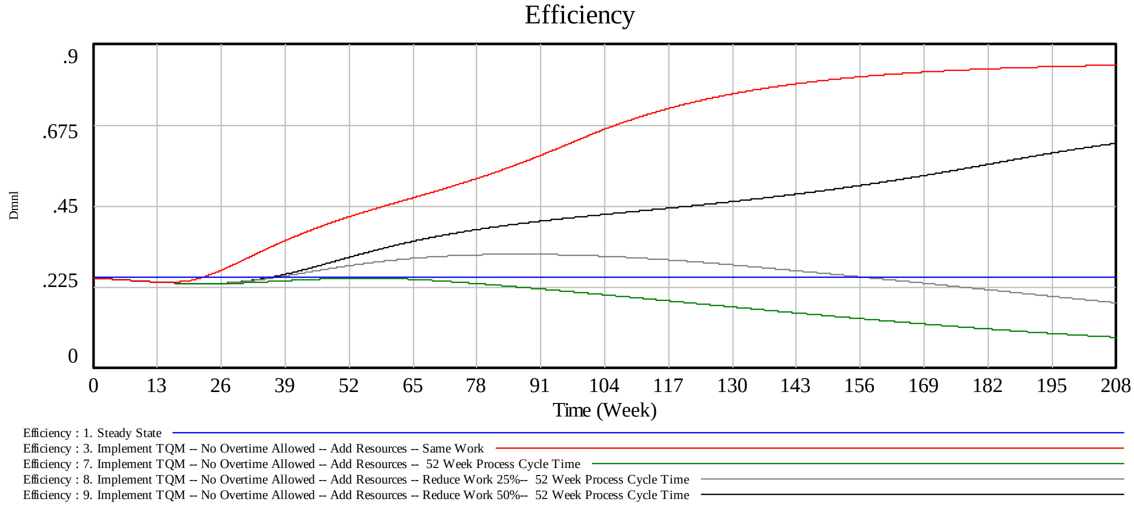

Figure 31: Impact of TQM Policy on System Efficiency with 52 Week Half-life Assumption

Source: Author's Original Work

The blue line in Figure 31 represents the steady state of the system and demonstrates that in the absence of change the model is stable and possesses steady-state equilibrium. This validates that the model itself was not changed by changing the time constants of the TQM policy. The remaining lines are not the same policy tests discussed in the Methodology. They are now defined as:

2. The red line now represents the implementation of TQM, with an assumed 26-week half-life for time constants but no policy of reduced work.

3. The green line represents the implementation of TQM, with an assumed 52-week half-life for time constants but no policy of reduced work.

4. The grey line represents the implementation of TQM, with an assumed 52-week half-life for time constants but a policy of reduced work load of 25% for one year.

5. The black line represents the implementation of TQM, with an assumed 52-week half-life for time constants but a policy of reduced work load of 50% for one year.

In varying these assumptions it is seen that a non-linear response of efficiency in the system occurs. The red and black lines represent conditions under which TQM still implements, however growth is slower than previously seen. Under the assumptions of the grey and green line TQM implementation fails. However, most interestingly in the grey line it appears that TQM might be succeeding for over two years before the attempted implementation fails. Typically this would be considered a failure of leadership to transfer ownership (decentralization) to the workforce. However, this research indicates that assumptions about the time constants and half-lives are another perfectly valid explanation for failure within this timeframe after apparent initial success!

Impact of Extending Half Life on Manning

Figure 32 is included to show the effect of a policy of maximum staffing the front line work force in conjunction with adoption of TQM. In all of the tested TQM simulations the unit is made “whole” by leadership granting the full manning of 60 people. However, after granting full manning the model represents a unit where people move in and out of the unit per normal Air Force standards. This abstracts a reality where leadership can give instant support but over the course of a year manpower returns to the pervious baseline equilibrium. This type of simulation also enables tested other manpower based policies; including overmanning and fixing manning at a level.

Figure 32: Impact of TQM Policy on Manpower with 52 Week Half-life Assumption

Source: Author's Original Work

Impact of Extending Half Life on Time Spent per Sortie

Figure 33 displays the effect of extending half-life on Time Spent per Sortie. As discussed, the Time Spent per Sortie was initially set at 10 hours and with TQM implementation expanded to 20 hours per sortie. Again the corner-cutting is seen in each of the scenarios. In each of the test cases the unit is unable to maintain the full 20 hours per sortie required for full TQM implementation due to resource limitations. However, for some time the unit, under every test case, is able to spend more than 10 hours per sortie. Over time, the longer half-life simulations find it more difficult to devote 20 hours to each sortie -- only the red line after 182 weeks and the black line, associated with a 50 percent reduction in work, can achieve full TQM implementation. The green and grey lines officially break in the 70^{th} and 160^{th} weeks, respectively.

The green line (no reduction in work) is a failure after approximately one year, and TQM would probably be abandoned after this point. This would have been a year of growing backlogs, half-starts and never quite getting ahead of any problems. The grey line (25% reduction in work) is the most interesting. TQM is neither an early success nor is it an outright failure. Instead the TQM program starts out strong but then maintains only a 12 hour per sortie time on average. This would equate to a ~20% implementation, and as seen in Figure 31: Impact of TQM Policy on System Efficiency with 52 Week Half-life Assumption would have resulted in a slow rise in efficiency for over a year. While this would have made the unit work harder, it would have seen some success, motivating continual attempts for nearly three years. This captures the problem with units that are able only slowly to implement some ideas. Eventually the sources of entropy outweigh the increases in efficiency, the early ideas stop paying dividends and new ideas are no longer generated, tested, and implemented. Eventually efficiency erodes and corner-cutting increases leading the system to return to the original equilibrium point. Yet the system is now encumbered by the TQM policy, leading to a lower efficiency than a system which had never attempted TQM. To correct this failure, leadership in the gray-line scenario would have needed to either further decrease the workload after one year or recommit to adding more manpower to bring the grey line back to the black line. In short, this situation was not a lost cause to begin with, but without continued leadership intervention (exogenous to the model simulated), TQM could not succeed under these assumptions.

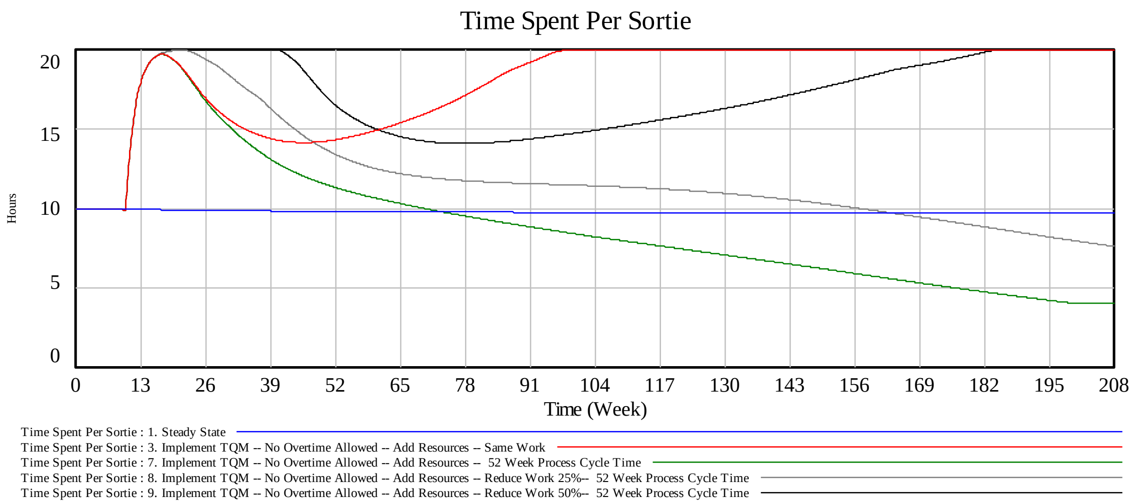

Figure 33: Impact of TQM Policy on Time Spent Per Sortie with 52-Week Half-life Assumption

Source: Author's Original Work

Impact of Extending Half-life on Experience with TQM

Finally, Figure 34 shows the effect of extending the time required to develop experience (familiarity) with TQM and its implementation. With a 26-week half-life (red line), there is a non-linear trend and a critical inflection point where the system can either catch or fail. But, with a 26-week half-life, TQM is implemented and the system succeeds (red line rises to 1). This same pattern is observed if the half-life is extended to 52 weeks and work is reduced by 50 percent (black line), though TQM takes slightly longer to reach the inflection point due to the slower iterative process-improvement cycles, thus CPI takes much longer to become successfully implemented. In fact, since the black line has reached only .8 after 4 years, it appears that it is never going to achieve complete success. With a 52-week half-life and a 25 percent reduction in work (gray line) or no reduction in work (green line), TQM fails. The TQM policy does not catch by the end of the first year, and after that, the reinforcing loop/policy of TQM works against the system. It is only if

TQM does catch that the reinforcing loop works to support adoption of TQM.

Also of note is that Experience with the Policy leads Efficiency of the system. Comparing Figure 34 with Figure 31: Impact of TQM Policy on System Efficiency with 52 Week Half-life Assumption, it can be seen that the rise and falls in Efficiency always follow the gains or losses in experience. This is because experience and alignment with TQM increase efficiency. The reason that the trend and inflection in Figure 34 (experience) do not match that seen in the efficiency plot (Figure 31) is that efficiency also fights the concept of social entropy; social entropy erodes gains over time.

While already noted that the green and grey lines represent implementations where TQM fails, in both cases experience is generated, and people perform their assigned tasks. However, as people are performing tasks, they are compelled to cut corners. The model abstracts this as not gaining experience with TQM. Certainly workers are learning behaviors and skills, but they are not gaining experience with TQM or the process of TQM. There is simply insufficient time available for these behaviors. This is a critical insight; just because people perform a task does not mean the unit gains net experience or necessarily gets better with the process. The reason is that the rate of experience gain may equal the rate of social entropy; while some experience is being gained, an equal amount of relevant experience across the system is being lost, leading to a net negative. This abstraction appears initially to depict experience gained, but overtime people leave the unit taking with them their initial experience with TQM, and no new experience with TQM is generated.

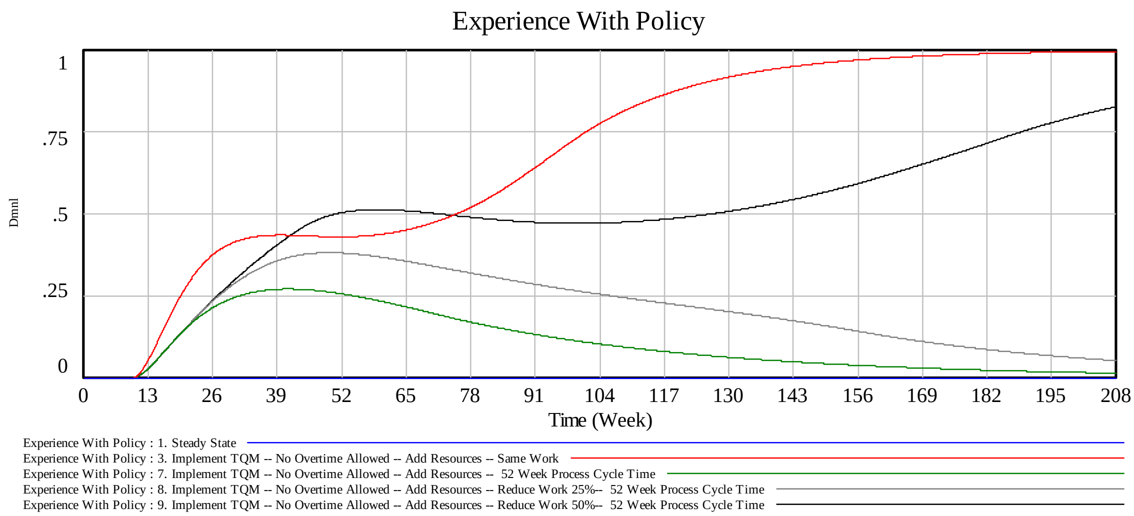

Figure 34: Impact of TQM Policy on Experience With Policy with 52 Week Half-life Assumption

Source: Author's Original Work

GAO report

In 1993, the Government Accountability Office (GAO) was requested to survey the Air Force and determine the implementation of TQM relative to the implementation across other DoD components.[14] The report selected two primary questions to rate effectiveness

- effect on external customers as reflected by overall organizational performance
- effect on internal customers as reflected by internal operating conditions.

The survey asked respondents (units) to rate performance in terms of productivity, reductions in costs, quality of products and services, overall service to customers, customer satisfaction, and timeliness. The result reported painted a positive implementation and value added by TQM processes; noting that 67 percent saw positive benefits, 28 percent

[14] "GAO Report --General Government Division," March 30, 1993.

deemed it too soon to judge, and the small remainder reported negative results.[15]

Discussion of GAO report

The 1993 GAO Report seems to possess information directly contradictory to both the theory of TQM and this body of research. GAO Report B-249779, dated March 30, 1993, defines five phases of implementation for TQM across the DoD and the Air Force. Phase 1 is effectively defined as having developed a mission and vision statement. The definition of Phase 2, titled "Just Getting Started," is:

> TQM efforts are in the early planning and implementation phase. Management has made a formal decision to start TQM and has communicated this to the organization. The organization's mission and vision have been articulated. A few quality structures, such as quality councils, steering committees, or teams, have been established, and some awareness training has been given. Preliminary quality planning has been done. Pilot programs or newly initiated installation wide efforts to improve quality are included in this phase.

Phase 3 is defined as, "Measures of quality and productivity have been identified and specific goals have been set." In GAO report B-249779, nearly 80 percent of Air Force organizations were either in Phase 1, 2 or 3 of implementation, and nearly all reported improvement from TQM as seen in Figure 35. Based on the literature and work presented in this thesis, Phases 1 through 3 should not produce value-added activity for any organization. Phase 4 is specifically listed as the stage where "The installation has a sustained TQM effort and has begun to achieve and document significant results." According to TQM theory and this research, no organization at Phase 1, 2 or 3 of implementation should report improvement. These activities upset "business as usual" and are a

[15] "GAO Report --General Government Division,", 4-6.

drain on organizational operation, they consume resources without producing results; not a net drain, only a drain. Moreover, theory would predict that many Air Force organizations would report issues. Although initially healthy organizations may perform better than those that are undermanned, across an organization as large as the Air Force, the expectation is that the initial reaction also would be across a spectrum.

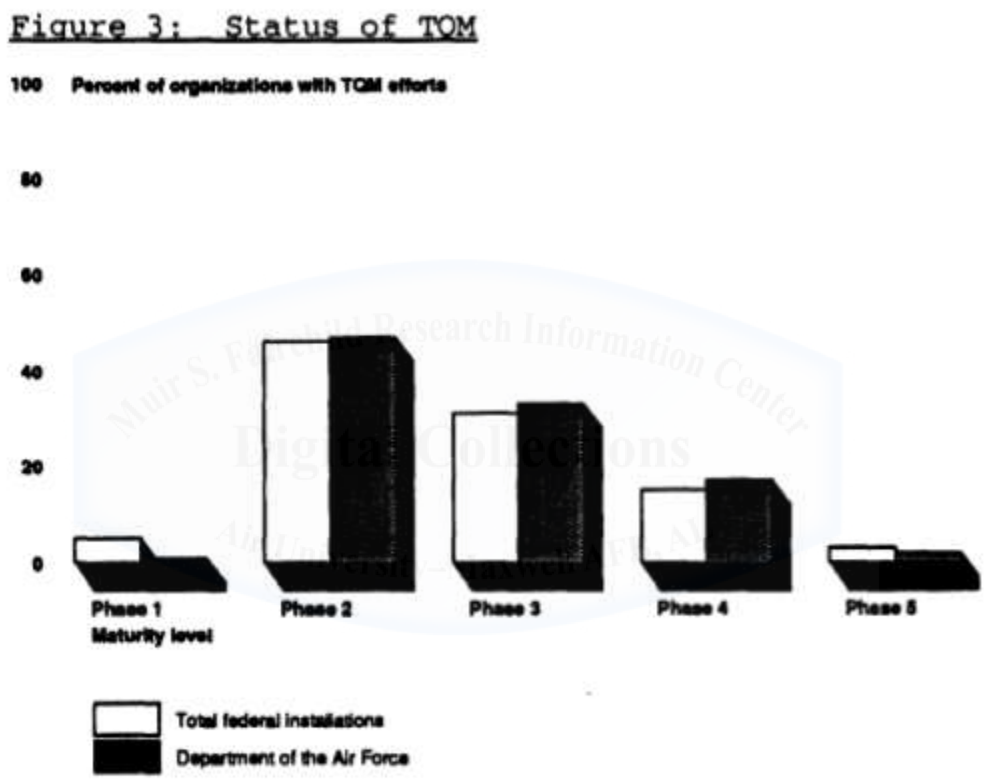

Figure 35: 1993 GAO Report, Status of TQM

Source: GAO Report B-249779, dated March 30, 1993

Figure 36 is not perfectly correlated with Figure 35 as it does not break out reporting by the stage of the organization. There should be five of these plots, one for each phase, however, the report does not include these plots. In this graph, it would be expected that organizations in Phase 5 would have a very positive impact. Units aligned with TAC were probably already in Phase 5 in 1988 when the DoD mandate went out.

However, for the nearly 80 percent of organizations in Phases 1, 2 and 3, there should be only two classes of answers. The 40 percent reporting "too early to judge" is probably fair for organizations in Phase 1. What is surprising is the Phase 2 and 3 units which clearly report something other than "no impact" or "negative impact." The most frequent answer is "somewhat positive" when, based on TQM theory and the answers in Figure 35, units should be reporting a decrease in performance. Most puzzling is that not a single unit reports a negative-impact result.

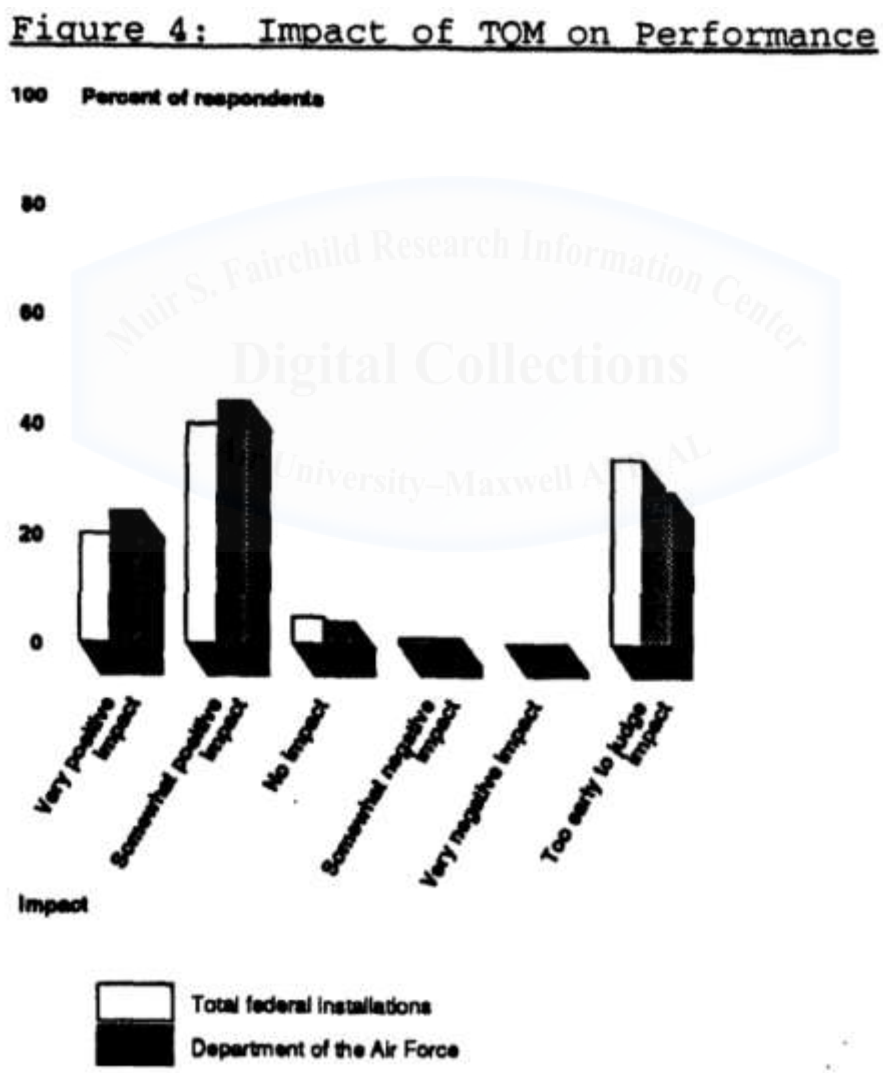

Figure 36: 1993 GAO Report, Impact of TQM on Performance
Source: GAO Report B-249779, dated March 30, 1993

Figure 37 merges the maturity phase (1 to 5) with the percent of organizations reporting increased performance. This is a partial answer. However, the trend and inflection of this plot do not align with TQM theory or the findings of this research. This trend and inflection line emerge in the model only if units are properly staffed and have process-cycle times which made learning possible. It is expected that Phase 1 cannot report an increase in performance as no work other than a mission and vision have been created. In Phase 2, the program has been set up and minimal training accomplished. Phase 3 is where effort is expended, but it is not until Phase 4 or 5 that performance improves. This graph indicates all Air Force units reported being in Phase 2 or beyond which creates the sharp jump in performance.

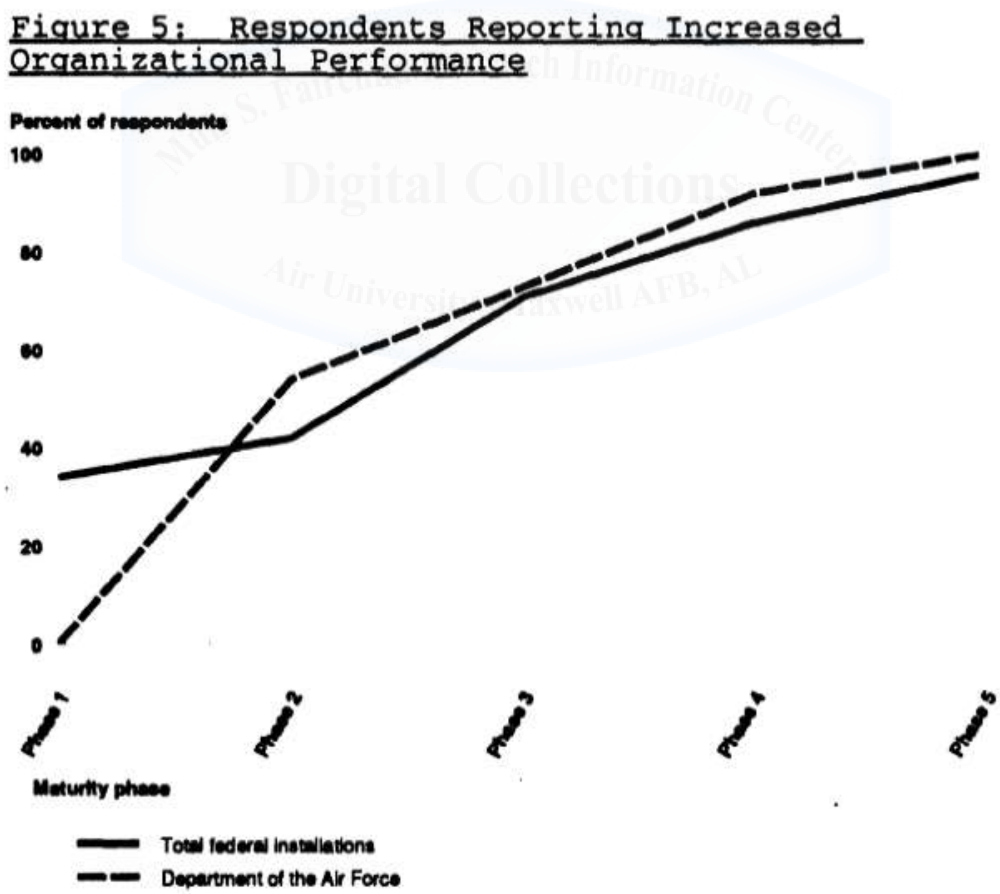

Figure 37: 1993 GAO Report, Respondents Reporting Increased Organizational Performance

Source: GAO Report B-249779, dated March 30, 1993

Thus, one might conclude that nearly 80 percent of Air Force organizations are reporting data inconsistent with theory. If this report was accepted by the Air Force, it indicates three potential issues. First, that leadership did not understand TQM theory or the impact of policy across time and phases if they did not push back on these responses. Second, units were reporting what they thought leadership wanted to hear. Finally and potentially most concerning, the unit commanders did not understand the policy well enough to correctly falsify an answer and just reported a positive because they wanted to appear "with the program."

The very units who were reporting positive gains were either intentionally "window dressing" the activities or were passing up feelings, not accurate metrics. At the very least, the result for Phase 1 and 2 should have logically been "too soon to judge." Even worse, this implies the midlevel leadership did not understand what the correct answer should have been. Moreover, by 1993-1994, 60 percent of units were still in Phase 1 or 2. Given the amount of time, most units should have been able to progress to Phase 4 based upon TQM literature. Either insufficient resources were available, or unit commanders were simply unwilling to implement for various reasons while reporting positives up the chain of command.

Previous authors noted that one of the cultural differences between Japan and America is that Japanese leaders trust metrics, but the Americans trust their "gut." If leaders when initially implementing TQM do not trust metrics then they are in effect breaking one of the most important process loops. [16] One definition of humor is the proximity to fear or danger and this relationship is clearly depicted in Figure 38; a

[16] Brown, Hitchcock, and Willar, *Why TQM Fails and What to Do about It.*

joke from the 1997 version of the Tongue and Quill on sycophantic behavior and quality processes: [17]

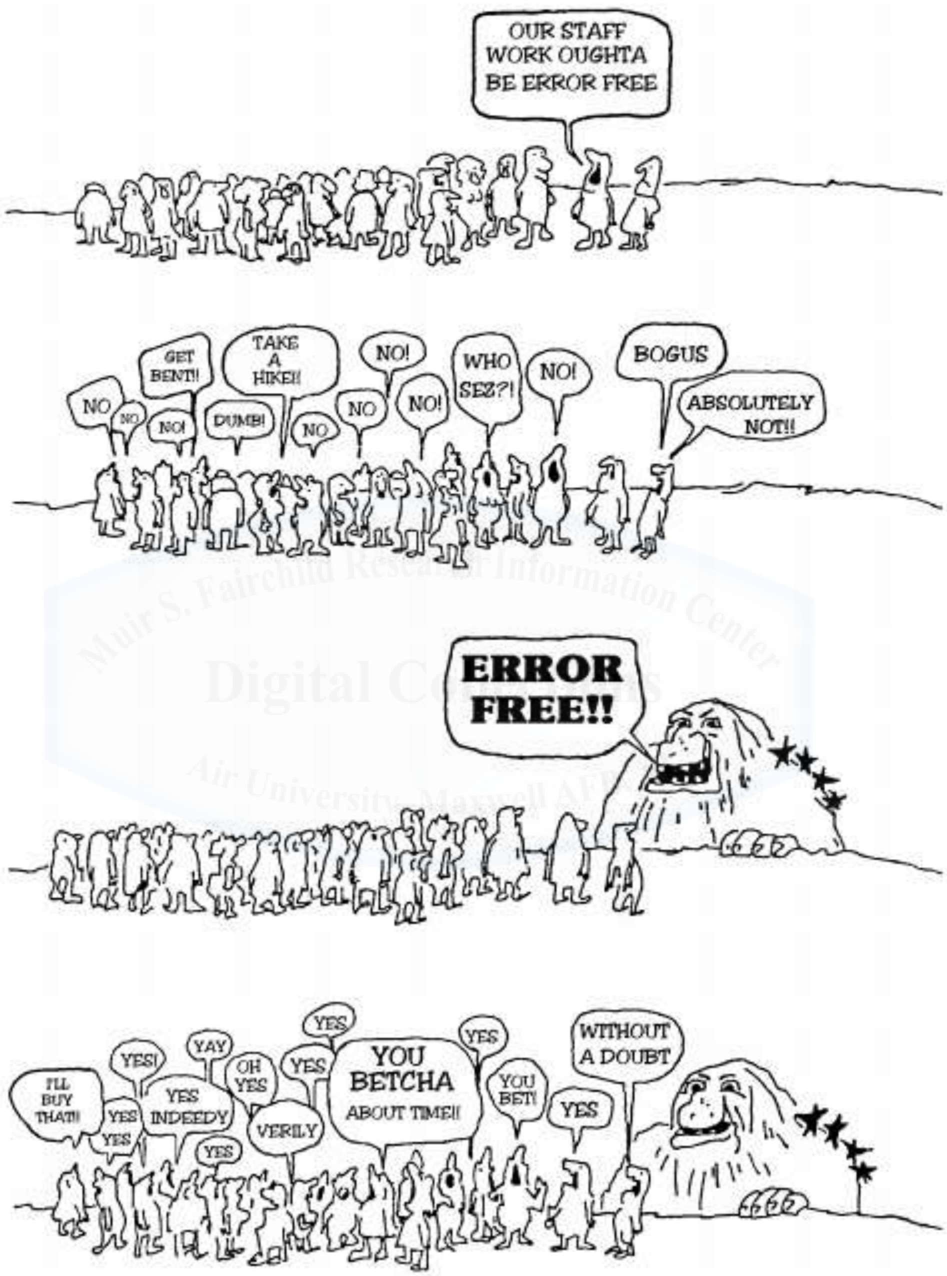

Figure 38: Air Force Tongue and Quill Joke on Quality Work

Source: The Tongue and Quill, AFH 33-337 30 June 1997

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[17] The Tongue and Quill, AFH 33-337 30 June 1997

The sad irony in these figures is that metrics and reporting are the lifeblood of a TQM implementation. If managers do not trust the metrics, they cannot adjust the process. These graphs would indicate zero trust in the ability to glean even the most basic information about implementation. Also surprising is the absence of a follow-up report in 1994, 1995, or beyond, which would be in keeping with the theory of TQM. Maybe this is why within the next two years TQM was abandoned and quality improvement efforts re-branded.

Section Summary

This modeling effort demonstrates that it is possible for external factors to change the behavior of a system in the process of implementing a TQM policy. In this section, variables dealing specifically with time were examined. Operating under one set of time constants, the policy of TQM is observed to take hold and increase efficiency of the system. Under another set of time constraints, the policy of TQM fails to take hold, and efficiency of the system does not increase, or declines. The success of TQM is partially context-driven by the type of work being performed. This provides an alternate argument to the original statement that the TQM process did not fail, the implementation did. A third option, that context made the process time-prohibitive, is now a valid argument for why TQM fails.

Most importantly, this model demonstrates that the policy of TQM is able to succeed under some contexts and conditions but will fail under others. The model was able to meet the initial goal of showing three cases: where TQM can succeed, where it can fail, and where it can succeed with proper leadership. This section suggests that the effort required to implement a TQM policy may be greater than leadership can support based on systemic time factors of Air Force missions. Leadership may need to implement policies of work reduction for long periods of time or dedicate higher-than-usual manpower levels. This finding is in line with Lin's, when he noted that some Air Force processes were more easily adaptable to quality processes.[18] This finding is also in line with the argument that "safe" fields exist within the Air Force.[19] The difficulty is for individual commanders to identify what type of unit they are leading. Commanders must determine the time constants of their unit, advocate for adoption of TQM, then demand additional resources or push back with a logical argument that TQM is incorrect for their mission. Finally, this work recognizes that there is a systemic issue beyond that of generating experience. The question is not only weather enough TQM is experience being generated, but can a unit capture the available experience appropriately. If a unit has a reason that it cannot flow back lessons learned, the value of the experience will degrade before the activity is performed again, and the cyclic process of TQM cannot function.

[18] Lin, "Air Force Total Quality Management: An Assessment of Its Effectiveness."
[19] Beck, "Total Quality...So What Is New?"

Chapter 5

Discussion

This work provides a systemic analysis of TQM policy as applied to an Air Force. The work has provided an alternate explanation to the existing body of reasons for the failure of TQM programs in the Air Force: time. The modeling and simulation based upon the theory of quality programs showed that the time in-between activities and the repeatability of activities heavily impact their probability of success. Quality programs are one side of a two-sided equation; they increase the efficiency of a system, thus reducing rework and waste. However, forces of social-entropy or chaos are continual degrading the efficiency of that same system. The strength and speed with which quality management programs can increase efficiency are directly dependent upon three critical time constants.

1. The time required for a person to gain competency with a task,
2. The time required for a unit to generate new ideas and,
3. The time required for new ideas to be implemented and evaluated.

The longer these time values (in days, weeks or months), the longer TQM will take to implement and the more prone to failure the policy becomes. The success of quality programs on a unit operates on a continuum. In some units, that align with "safe" fields whose systemic nature closely mimic manufacturing, quality management programs may easily take hold. As these three time constants get longer, and the strength of quality programs decreases with social-entropy, the more difficult the implementation of quality programs becomes until at some point it is impossible to build in quality to a process.

To conduct this research, a deductive system-dynamics model was constructed based upon TQM literature. The model was designed to represent a pipeline system where output depends upon system efficiency. For clarity and communication to the target audience, the model used the language of Air Force operations. The System Dynamics model developed in this thesis was verified to abstract and possess the same core elements as discussed in the TQM literature. The model was validated to possess a steady-state equilibrium; that is, that it operates with a consistent baseline or represents a system with a natural state to which it seeks to return. Moreover, component tests of five structural elements, referred to as Molecules of Structure, were conducted. These included:

- A work pipeline with task completion
- The idea of efficiency or quality
- Experience
- A workforce (resources)
- The idea of applying policy to this system

Testing showed that each behaved as expected in abstracting real-world behavior. Within the system-dynamics methodology, this means model outputs were examined to ensure their trend and inflection were in line with expectation. The Results section examined the impact of integrating the TQM-policy model with the pipeline model. Additionally, the effect of various policies of reducing work and increasing manpower at the time of TQM adoption were tested. The impact of these different policy tests on system efficiency better illuminates the spectrum across which quality programs are likely to be successful in the Air Force.

This work does not refute the claim that quality can be added to all management activities, nor does it argue against empowering frontline leadership to address and solve problems at the lowest level. These are nearly universal truths as a military seeks to create a competent, articulate and capable war-wining force. However, as noted in the Literature Review, quality management was born in manufacturing.

Previous authors, completing point-to-point comparisons, have already conducted myriad analyses which have identified difficulties in seeking to extend quality programs to Air Force operations. These authors conclude:

- The Air Force could naturally align with only nine of Deming's 14 points, though the remaining five could potentially be adapted
- Problematic metric development and difficulty defining what adds value
    - Improper metrics incentivizing the wrong behavior
    - Compensation structures and the promotion system working against teamwork and decentralization of process
- Problems when critical functions are outside the control of a unit or organization, as occur when contractors control processes or a contract forbids interference
- Difficulties associated with non-uniform processes, such as education[1] where people are the output, the production of documents such as contracts or requests for proposals, and situations involving the creation of unique prototypes or one-off missions.

This work now adds the systemic issue of time as a new argument to why quality programs have failed and may continue to fail.

Several recommendations on the role of quality programs and their applicability to Air Force operations emerge from this work. These recommendations may be useful in determining if quality programs are a net value-added activity when considering future implementations. First, this investigation provides insights to the impact of time constants inherent in any application of TQM policy to a repeatable process. This is a variable mentioned but not currently discussed as a threat in the

[1] Education is different from training. Training has its unique difficulties but from a TQM perspective are different than education and quality processes seem to better align with training activities.

literature on Air Force and quality management. Before implementing quality policies, leadership must have a good understanding of these time values in their unit. This work cannot suggest a “golden ratio” for the average time that a person should stay on a job to create a most efficient implementation of a quality-control process. However, the concept of half-lives in learning curves suggests that it requires a factor of three to gain full experience. Thus, unless a policy enables a person to perform a task for at least three times longer than it takes the average person to gain average competency, TQM will be not be a viable set of policies for improving efficiency/quality. For example, if it takes a year for a mechanic to become competent in replacing engines, the average time to move mechanics must not be less than three years if TQM is to be viable. Moreover, there can be a time required that is so long that the quality process will fail as it extends beyond the human capacity to remember. It does not take a model and simulation to argue that at the extreme, TQM will be impossible. Consider a task performed only once a year. Realistically, no improvement will be possible for this task as a consequence of a TQM-style policy. Quality would need to be engineered or tested into such an infrequent activity.

Second, this work reveals a need to consider system social-entropy, or the pull of returning to “business as usual,” and other various potential degrading forces. While the above time constants are factors that link to the period required to improve the efficiency of the system, efficiency, as defined in this work, operates in a balance between improving as a consequence of adherence to TQM and degrading due to social-entropy. Thus, even if the time values associated with a specific task appear favorable to change associated with TQM, there may be large amounts of entropy that make implementing TQM non-viable. For example, if the process is expected to change or requirements are expected to change quickly, this will provide large amounts of entropy to the system and slow TQM adoption. If the mix of manpower is expected to change rapidly, such as AEF deployment cycles of six months, it is likely that TQM is non-viable. The entropy associated with such frequent changes in personnel will break the iterative cycle and make continuity of improvement in deployed environments nearly impossible. Sources of entropy may even span the mix of activities being performed. For example, if technology is maturing rapidly and production runs are longer than development times, it may be impossible to reach levels of efficiency that deliver quality in the face of such high entropy.

Third, the work suggests the value of a more nuanced observation about experience and learning. Air Force officers noted that one potential problem with TQM and the military was that some activities, such as experience from combat, cannot be trained directly.[2] While the model is abstract, there is a clear delineation between the act of adherence to process (generating experience) and a store of experience (keeping experience). This suggests consideration of a new issue of system experience. The question: not only is enough experience generated for quality procedures to have an effect but is management capturing, or even able to capture, the appropriate experience? Is the net experience captured a positive gain, system wide, or does the individual reap experience while performing a task that degrades experience with other processes? Furthermore, is experience put back into the system or does it leave with the individual? In the Results section, it emerges that under some conditions, while work is being satisfactorily completed, the stock of experience is decreasing even in as new work is being successfully completed. This may seem illogical but is possible due to time-delayed causal effects. For example, consider a situation of limited resources where firefighting behavior has become the norm. Under these conditions, people may expertly solve the problems of the day but not improve the functioning of the organization. They may become better and

[2] Add citation here

better at firefighting and solving emerging problems, but this is different experience than would be gained by implementing a repeatable process.

Fourth, this work makes a systemic argument against the DoD's initial assumption that TQM could be implemented agency-wide as a way to reduce costs and continue performance in a fiscally constrained environment. While it is true that TQM promises either to maintain performance with less resources or increase performance with equal resources, the promises includes the key words "*over time*." "Doing more with less" is possible but takes large upfront investment - so much upfront investment that TQM could never be implemented successfully across an entire system, be it a military or civilian corporation. The resources required for specific training would "hard break" any organization if it attempted a system-wide change. This is why GM worked with Toyota to create the New United Motor Manufacturing or NUMMI facility, implementing TQM at one plant, not across all factories. Not only did they create a better chance for success by limiting TQM implementation, they also created a new environment where quality managed process could be built from the ground up, unencumbered by existing barriers. For the DoD, encumbered with existing culture, regulation, and best practices, a successful dramatic shift becomes unlikely. Thus one could not, even according to TQM theory, instantly implement the strategy across the DoD - there would be insufficient resources.[3]

As an aside, one can note that DoD implementation in the 1988 to 1993 timeframe ran into the additional problem that system-wide budget cuts had already begun. In its initial phase, TQM requires more resources rather than less. One cannot successfully implement TQM while reducing manpower or budgets. One can reduce manpower or

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[3] Most importantly, if the DoD applied any policy system wide it would be subject to massive system-wide risk if the policy was flawed.

resources after TQM has "caught," but TQM efforts would theoretically need to start three to five years before reductions.

Fifth, as this deductive model is sensitive across a range of variables and assumptions and possesses no numerical validity, the following claim is speculative.[4] However, the model indicated a large sensitivity, a greater sensitivity than to other variables, to manning fluctuations over a long time (greater than one year). While one or two persons can be replaced by others working overtime, a reduction of ten percent in manning could be the difference between a successful implementation of TQM and a failure. Manning and the replacement rate for the Air Force is vastly different than in the civilian sector. One reality of Air Force operations is that the Unit Manning Document may not reflect the reality of the front-line work force. For the example of a unit launching sorties, the difference between a manning document of 60 and 54 people or 48 people is substantial. Implementing TQM on an undermanned unit is a recipe for breaking the unit, not improving its efficiency. TQM cannot be implemented in a unit when reducing manpower. Realistically it must be implemented in a unit with manpower equal to the task at hand.[5] When Air Force authors write that an external factor, such as manning, can make or break a TQM implementation, they are correct.

Finally, as with the previous point, the model possesses only deductive validity and insufficient scope to make claims about specific implementations of TQM; this would require deductive tuning. However, the behavior of the model can be used to comment on the concept of a slow ramp-up to TQM. *Why TQM Fails* noted that TQM usually succeeds

[4] A model would need inductive tuning and statistical validation to gain this power. This is the fourth and final step in the System Dynamics method, used for consultation but not typically performed in abstract or academic work.
[5] And not the manning that the military implements where people are deployed, sent on special tasks, subtasked to other units or constantly on TDYs or training. Actual bodies in positions performing the physical mission.

in companies that are either just getting started or just about to fail.[6] One might argue that slowly implementing partial TQM, just the quality portion without the cultural and leadership changes, might make sense; which is what the Air Force was advocating in AFSO21. In the example of a unit launching sorties, this might be tantamount to saying instead of the requirement changing from 10 hours per sortie to 20, would increase only from 10 to 12. Placing a smaller burden on the unit or organization, it would have a better chance of implementing that change. The problem is a second-order consequence of a longer implementation time. TQM, even when fully endorsed, takes a minimum of three years in a manufacturing environment to extract value, and usually requires over five years to pay for itself. If the slow ramp-up pushes this time out longer, it delays payback. With respect to the Air Force's existing system, a partial implementation will almost certainly exceed the time that employees and leadership stay in an organization. This will erode support for the policy and make the policy more susceptible to increases in social-entropy, thus delaying the benefit and eroding support. This type of partial implementation can lead to an environment with increased skepticism towards the policy. These injections of entropy make it less likely that TQM will succeed and increase the institutional inertia. Moreover, after a single failed implementation, it has been observed that subsequent implementation attempts become harder.[7] This deductive simulation has represented how setbacks can impact the adoption of TQM and indicates fragility associated with changing a system and its desire to regress to its original form.

Based on the model, TQM can be implemented across some Air Force units, like maintenance and logistics, which contain numerous, frequent, repeatable processes which can be captured in metrics for analysis and

[6] Cite it
[7]Cite the comment about renaming the same old program.

improvement. Other units, like contracting or acquisition units, do not have processes frequent or repeatable enough to benefit from TQM application. In these cases TQM is a net drain, as quality will have to be "engineered" into process, and the requirements of the quality program will not pay efficiency dividends. Applying TQM Air Force-wide is an impossible mission and should be limited to those areas where leaders can make a solid argument for alignment with quality management theory.

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